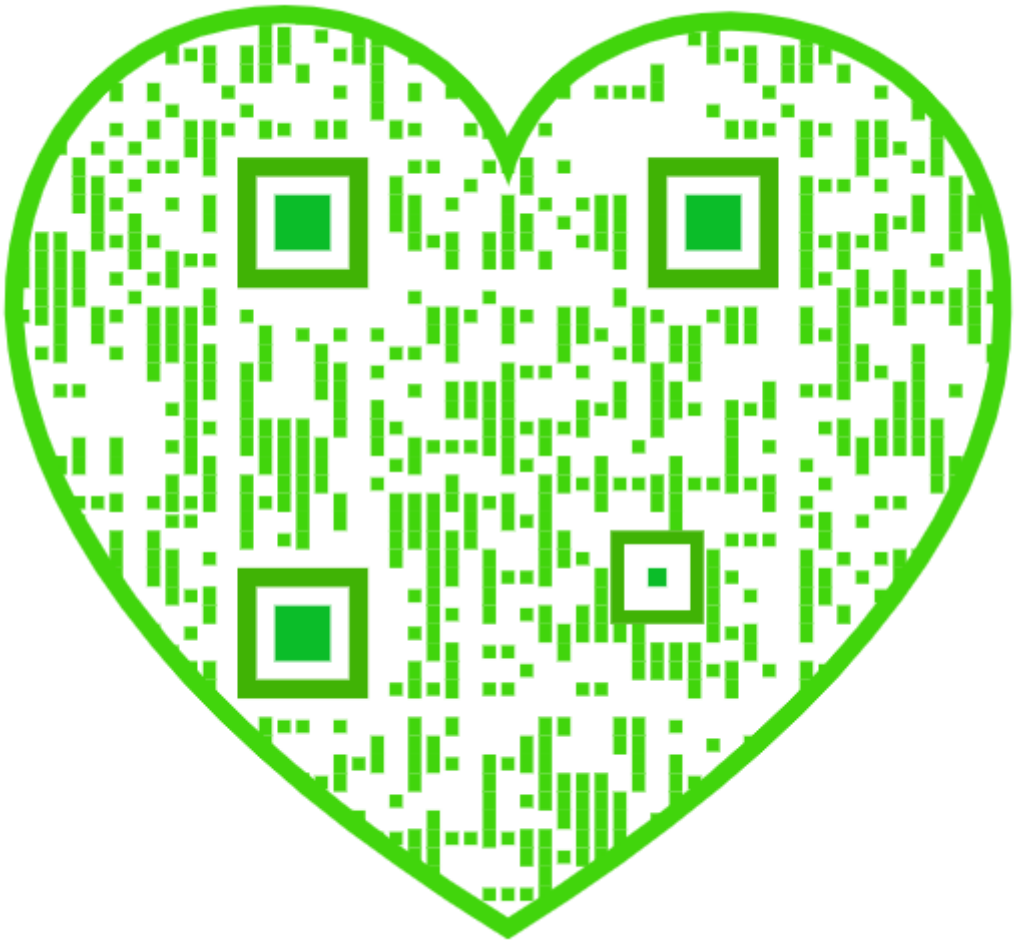

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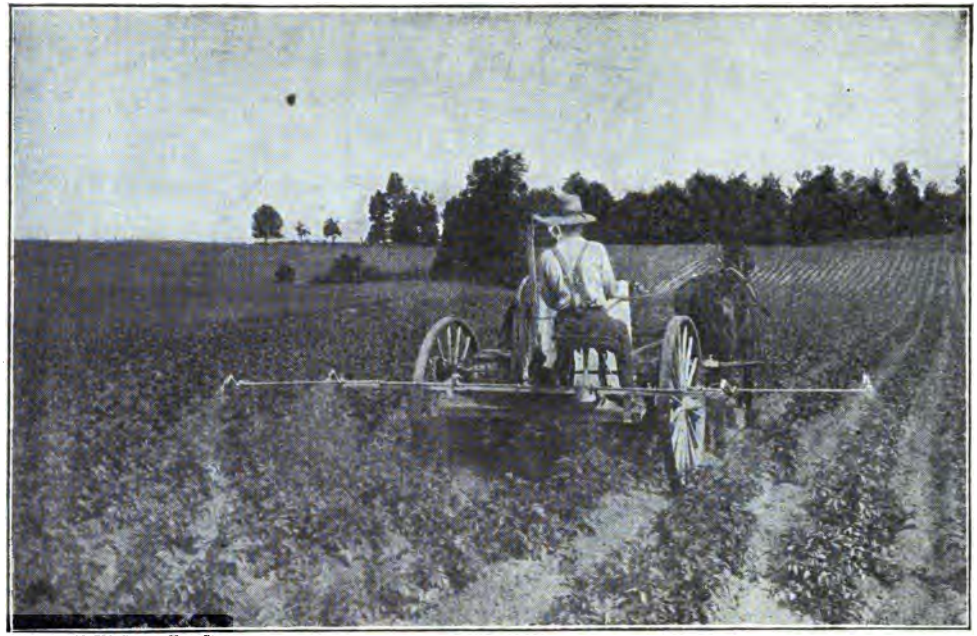

Courtesy (N. Y.) Geneva Exp. Sta.

SPRAYING IN A NEW YORK POTATO FIELD

In 1904 the net profit received for spraying was as high as $60.00 per acre. (See p. 139.)

THE POTATO

A PRACTICAL TREATISE ON THE POTATO, ITS CHARACTERISTICS, PLANTING, CULTIVATION, HARVESTING, STORING, MARKETING, INSECTS, AND DISEASES AND THEIR REMEDIES, ETC., ETC.

SAMUEL FRASER
Assistant Agronomist, Cornell University

ILLUSTRATED

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To

James Scott Gordon

WHOSE LIFE AND WORK ARE AN
INSPIRATION TO MANY

Gift
Mrs A.P. Ahlmacker
2-7-34

PREFACE

THE literature issued on the subject of potatoes during the past three hundred years would form a large library, many works having been published in the United States, the United Kingdom, France, Germany, and other countries. It is safe to say that no plant has aroused a deeper interest than "the noble tuber." Its very existence to-day is largely due to the efforts of enthusiasts. Several of the older writers were keen observers and acquainted intimately with the history and character of the potato, and modern authors include the names of men who are eminent in the scientific world. The vast amount of research and demonstration carried out by the experiment stations of this country during the past ten years, and the fact that every station has done something in this line, show the breadth of the subject and furnish material hitherto unobtainable. The excellent research work now being carried on in Europe, especially in France, Germany, etc., and more recently established in Ireland, indicates a demand for more information about this crop. We feel that the "science of agriculture" is a reality; that, like every past generation, we are on the eve of great discoveries; that something of the laws governing plant nutrition and growth will shortly be revealed, that we may be able to prevent rather than cure the troubles which assail our plants. To be of

any use, scientific research must be rigidly accurate in its observation and merciless to fallacy in logic. Once a principle is proven it is of no use unless applied, and the man to apply it is the farmer.

At the present time it behooves us to divest ourselves of prejudice, whether of tradition or custom, which might tend to warp our judgment and treat as debatable assumptions which long-established association have made shameful to doubt, but which, undisturbed, would make the discovery of truth impossible. To-day theories are no longer revered because our fathers believed in them. The search-light of all-prying Science illuminates the whole field of agriculture, and has led men to doubt and call in question even truth itself, in order that they might expose those things which are not true. It is by this means alone, by this attitude of questioning all statements and theories, both the truth and the untruth alike, that we can form a just estimate of what is true. That which cannot stand the fire may rightly be esteemed dross.

In this book the endeavor has been to collect many scattered facts from many sources, and present these—along with experience derived by growing potatoes for several years, commercially and experimentally, in two continents—in the hope that these data will be of value to the reader.

SAMUEL FRASER.

CORNELL UNIVERSITY,
Ithaca, N. Y., 1905

Note.—With the exception of Figs. 26, 27, 28, 29, 30, 31, 43, and 44, which were kindly loaned by the makers of these implements, and those in which credit is given in the text, all illustrations have been prepared by the Author.

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ABBREVIATIONS USED

U. S. D. A.—United States Department of Agriculture, in connection with reports or bulletins.

E. S. R., V:33—Experiment Station Record, Volume V., page 33. Issued by the United States Department of Agriculture, Office of Experiment Stations.

Experiment Stations in the various States are designated by the common abbreviation for the State—as, "Wis.": Wisconsin. Where there are two stations in a State, the particular one is designated—as, New York (N. Y.) Cornell. The number of the bulletin follows. Some States issue their bulletins in volumes, thus: Tenn. Bul., Vol. XI., I., p. 116—Tennessee Bulletin, Volume XI., No. I., page 116.

Pa. D. A.—Pennsylvania Department of Agriculture. State Departments of Agriculture are abbreviated in this manner.

Can. Exp. Farms Report, 1901, p. 117—Canada Experimental Farms Report for 1901, page 117.

Ont. Agr. Col. and Farm Report, 1898, p. 158—Ontario Agricultural College and Farm Report for 1898, page 158.

Hort. Trans., Vol. I.—Horticultural Transactions of England, Vol. I.

Nat. His. of Car.—Natural History of Carolina. By Mark Catesby, F.R.S. Second Edition. London.

Proc. Assoc. Prom. Agr. Science—Proceedings of the Association for the Promotion of Agricultural Science (America).

THE POTATO

CHAPTER I

HISTORY AND BOTANY

THE potato (*Solanum tuberosum*), also called "white potato," "Irish potato," "English potato," or "round potato," is a native of the elevated valleys of Chili, Peru, and Mexico, one form of it being found as far north as Southern Colorado. The wild potatoes of Chili differ from the cultivated form, in that they produce seed-balls more freely.

Tobacco, tomato, egg-plant, capsicum, henbane, and belladonna all belong to the potato family, but of this large family of 1600 species but six bear tubers. Some of these latter—as, Darwin's potato (*Solanum maglia*)—were thought to have some value for crossing to produce a blight-proof new race, but so far success has not been attained in the latter respect. A variety of *Solanum commersoni*, another tuber-bearing plant, is now being boomed in Europe as a substitute for the common potato. The Arizona wild potato (*Solanum jamesii*) has been grown for many years in this country in various places, but its tubers are small and of little value. The Mexican or Central American potato (*Solanum tuberosum* var. *boreale*) is found native in Colorado.

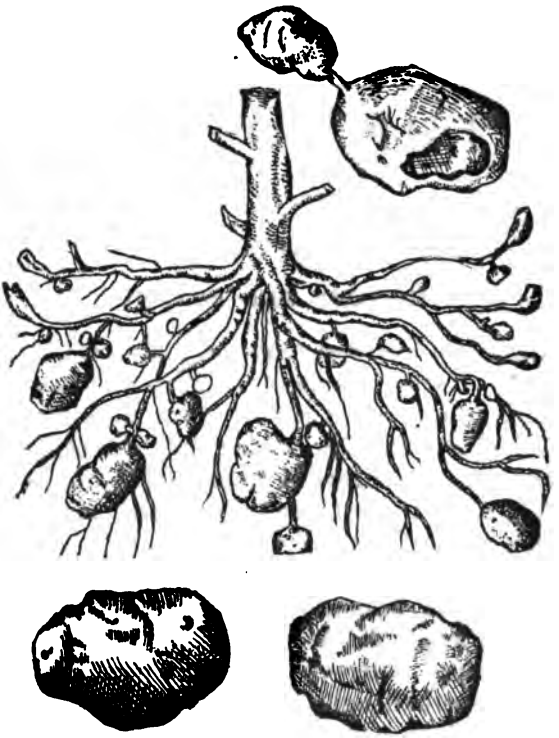

FIG. 2—COPY OF ENGRAVING OF THE VIRGINIAN POTATO IN GERARD'S "HERBAL," PRINTED IN 1636

(Compare with photograph, Figs. 5, 6.) In England the name Virginian potato was used to designate its source.

The potato was probably introduced into that part of the United States now known as Virginia and North Carolina between the middle and close of the sixteenth century. It is claimed that in 1586 colonists returning from Virginia probably took the potato with

them to England. The Spanish had previously carried it to Europe. Gerard's "Herbal," published in 1597, describes the potato, and the edition published in 1636 contains a woodcut representing the potato as it appeared about three hundred years ago (Fig. 2). The potato was more readily appreciated in this country than in Europe, and by the year 1722 it was a common article of food among the whites and Indians in Virginia and Carolina.[1] In Europe, with the exception of Ireland, potato growing made little progress until the middle of the eighteenth century.

The potato (*Solanum tuberosum*) is an annual, but is virtually perennial by means of its tubers. It has smooth, generally solid, more or less quadrangular, herbaceous stems, which often attain a hight of two to five feet. The stems are often furnished with membranous wings at their angles, and bear compound leaves formed of oval leaflets, between which are often found small, leafy growths. The flowers (Fig. 3) are borne in clusters, and have an entire, wheel-shaped, five-pointed corolla, varying in breadth from one to one and a half inches, and in color from pure white to purple. It is often claimed that many varieties do not flower, and of those which do a great number never bear fruit. This dearth of fruit is generally attributed to lack of pollen. In many varieties the stamens have degenerated, or do not open to let the pollen out.[2] Conditions seem to have an influence, as a variety may bear abundance of pollen and mature seed in one district, but not in another in the same year.

---

[1] "Nat. His. of Carolina," by Mark Catesby, F.R.S., 2d ed. [2] Halstead, Proc. Assoc. Prom. Agr. Science, 1888, p. 33, "Potato Flowers and Fruit."

The idea is prevalent that potatoes do not bloom so freely now as formerly. The facts do not tend to confirm this. Mark Catesby, who was in this country in 1722 and 1726, wrote that "in Virginia and to the

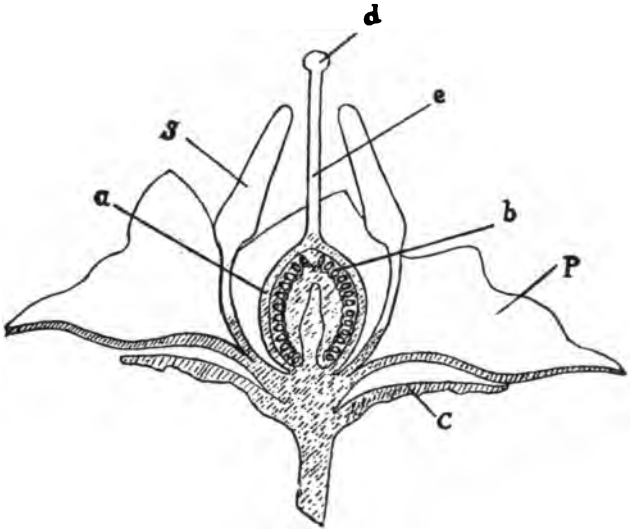

FIG. 3—SECTIONAL VIEW OF POTATO FLOWER
(*Diagrammatic*)

a—Ovary. *b*—Ovules, which finally become seeds. *c*—Calyx, made up of green-colored leaves. *d*—Stigma. The pollen attaches itself at this place. *e*—Style, down which the pollen-tube passes to the ovary and ovules. *p*—Petals, white to purple in color. *s*—Stamens. The thick upper portion bears the pollen, and is known as the anther.

north thereof, they [potatoes] are annuals, and produce no flowers, while in Carolina and the Bahama Islands they produce flowers." Many varieties existed at that time, particularly in Virginia, and five kinds were common—the Common, Bermudas, Brimstone, Carrot,

and Claret potatoes. The Bermuda potato was the only one that had a white flower, the flowers of all the other kinds being purple. This was the only variety that had a white skin, and was white fleshed. It was round in shape, more tender, and more delicate to raise than the others, and did not keep so well.[1]

George Don, in 1831, enumerates several English early varieties, and says that "none of the above sorts, when true, produce blossoms."[2]

At Wyoming Experiment Station,[3] in 1895, out of 56 varieties grown 14 did not bloom, but in 1896 but 4 varieties failed to bloom out of 56, and only one variety, Blue Victor, failed to bloom in one of the two years. In other parts of the State all the varieties grown came into bloom. In New York, during 1904, the variety Blue Victor was profuse in its bloom, and bore abundance of seed-balls. Out of 300 varieties I have followed closely, having grown many for several years, I find that it is seldom that a variety will not bloom at some time in its life, and I am sure that many of the heaviest-yielding varieties bloom as freely as those of inferior merit. At Wyoming Experiment Station the ten heaviest yielding varieties all came into bloom both in 1895 and in 1896, in experiments conducted in various parts of the State.

The fruit, or seed-ball, is a globular or short oval berry, either green or green tinged with violet, brown, purplish, or yellowish in color, and from three-quarters to one and a half inches in diameter. It contains

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[1] "Nat. His. of Carolina," by Mark Catesby, F.R.S., 2d ed.
[2] Don's "Gardener's Dictionary," 1831–8, Vol. IV., pp. 400–406.
[3] Wyo. Bul. 32, pp. 54–63.

small white kidney-shaped seeds embedded in the midst of a green and very acrid pulp (Fig. 3). These seeds are sown for the purpose of raising new varieties.

The main vertical underground stem varies in length with the depth of planting. This stem branches at intervals, and each branch enlarges at the end to form a tuber (Fig. 12). Usually from two to four roots start from the vertical underground stem at the base of each tuber-bearing branch, but roots may start where such branches are absent. This characteristic growth may be seen by growing a potato in a barrel half full of soil and manure, and watering it well; then, as the stem grows, place soil round it, thus increasing the length of the underground portion and the number of tuber-bearing branches. The tubers may be formed above ground, and whenever they are abundant in the axils of the leaves there are few or none below ground.

FIG. 4—KIDNEY-SHAPED POTATO (*Does Pride*)
Showing the alignment of the eyes, and that the terminal buds tend to start first. Note the short, thick, desirable shoots.

The tuber is an underground stem, and the eyes on it are equivalent to the leaf buds on a stem of a young peach or ailanthus. They are arranged more or less spirally in both cases (Fig. 4). From the eye a number of buds may start; hence, in the case of new and expensive varieties, the tubers may be split through the

eyes, if desired, and a shoot obtained from each half. As each shoot sets a root it may be broken off and transplanted, and another may start. By these means and great care a pound of seed tubers has been made to yield 2,558 pounds of potatoes in one season.

Historical Note.—The early history of the potato is obscure. The most authentic information I have secured is that Sir Robert Southwell, the President of the Royal Society of England, at the meeting held December 13, 1693, stated that the potato was brought into Ireland by his grandfather, who obtained tubers from Sir Walter Raleigh, after the return of his expedition from Virginia. This was in the year 1584. It is now believed that Sir Walter Raleigh fitted out this expedition, but did not lead it personally, and never was in Virginia.

Timbs' "Curiosities of History," page 233, places the date of its introduction to the British Isles as 1586.

CHAPTER II

SOME CONDITIONS INFLUENCING GROWTH AND DEVELOPMENT

It is common knowledge that a certain amount of heat and an adequate supply of air and moisture are essential for plant growth. All plants that have green leaves require light, in addition, to enable them to assimilate carbon dioxid from the air, dissociate it into its component parts, and elaborate the carbon into such complex substances as starch, sugar, and other carbohydrates.

Influence of Light on Yield.—E. Pagnoul[1] placed colored glass over different potato plants. Two plants under darkened glass elaborated 31 and 20 grams of starch respectively, while those under ordinary glass elaborated 170 and 110 grams; at the same time plants under normal conditions elaborated 223 and 361 grams. To the favorable influence of abundant light this writer attributes the large yield of potatoes in a season when the aggregate number of hours of sunshine is unusually large. At Wisconsin Experiment Station coldness and cloudiness were believed to be the causes of a poor yield.[2]

The Amount of Moisture.—The amount of water the plant can obtain from the soil is closely cor-

[1] E. S. R., V., p.116. [2] Wis. Report, 1902, p. 188.

related with the mode of development. If the soil is very dry, and particularly if the tuber is cut, the seed tuber may be so weakened by loss of moisture that it cannot grow. If a tuber has access to but a small amount of water, there will be little or no root development, with little formation of leaf shoots, but tubers will be formed. Advantage is taken of this fact when small early potatoes are required, the tubers being placed in sand, in a cellar, when small tubers will form, but none or few leaves. Under certain conditions, with an abundance or excess of moisture, numerous leaf shoots and roots appear, but no tubers. An increase in the supply of moisture in the air has been found to favor the development of leaves on the shoots, where only scales were formed in an insufficient supply of moisture.

Respiration.—We may say that all plants breathe or take in oxygen and give off carbon dioxid. With potatoes this is a necessary function, and if checked, growth is injured. It is probable that light induces some conditions more favorable to increased respiration than darkness; hence, if the object is to store potatoes, it will be better to hold respiration at its lowest point and keep them in the dark. Respiration cannot go on without force or energy, and as this must be supplied, at least partly, from the tuber, it follows that active respiration will be attended by loss of weight, and this goes on very rapidly when the tuber sprouts.

If we wish to "sprout" tubers, the best conditions for doing so are still undetermined.

Influence of Temperature on Respiration.—All plants have a range of temperature at which respi-

ration is normal. The minimum, optimum, and maximum temperatures have been ascertained for some plants. Young wheat plants will respire at as low a temperature as 28° F., or below freezing-point. The optimum temperature for wheat is about 104° F., while that of potato plants is about 113° F. The maximum for wheat is 113° F., while that for potatoes is about 131° F. In other words, the potato respires best at about 113° F., but should the temperature go above 131° F., the respiration will be somewhat less than before, and the vitality weakened; hence, after a hot spell, when the temperature exceeds the maximum for respiration, it is noticeable that the potatoes fail and become more susceptible to the blight or other troubles, owing to their impaired constitution. By selection we might procure plants of greater vitality, capable of standing the higher temperatures, which would enable them to be better "disease-resisters." Present-day potatoes thrive best in a cool climate.

Influence of Temperature on Growth.—The minimum temperature for germination of potato tubers is about 50° F.; hence, in the Northern States early planted tubers make little or no growth unless planted shallow, and this is not desirable, except, perhaps, for the earliest varieties. It is better to germinate the tubers in the barn before planting, thus saving time (see Chapter VI., "Sprouting Potatoes").

Potato Roots.—Generally speaking, far more attention has been paid to the stems and leaves of plants than the roots, yet in order to cultivate the soil in a rational manner it is essential to know where the roots

are, their character, and requirements. Examination of the roots of Early Ohio potatoes,[1] made July 5, 1899, forty-three days after planting, about the time the crop received its third cultivation, showed that at this time there was little growth of fibrous roots—only the skeleton system supplied with numerous delicate root hairs. The seed tuber appeared to be sound and whole, but on closer examination it proved to be but a shell. Only a few eyes on the upper side of each tuber produced shoots; thus one hill produced three stalks from two eyes, and another had seven stalks springing from five eyes. The latter plant had more numerous but smaller roots than the former. Twenty-five small potatoes were set on the first plant, the largest of which were the size of a large pea. At this stage of development the main portion of the roots was in the surface eight inches, a few roots reached to the depth of eighteen inches, but the greatest root growth was in a horizontal direction. The roots from each hill had already met and interlaced, some having reached a length of two feet, the plants being three feet apart. At six inches from the hill some of the main lateral roots were but two and one-quarter inches from the surface of the ground, while midway between the rows their depth was barely three inches from the surface.

Further examination of Early Ohio potatoes seventy-two days after planting, when the tubers were nearly full size, showed that the main root growth was in the upper foot of soil; several of the large horizontal roots were within three inches of the surface, and one was but one inch deep. Some of the vertical roots reached

[1] N. Dak. Bul. 45, p. 541.

FIG. 5—PLANT OF VERMONT GOLD COIN (VIEWED FROM ABOVE)

Grown under field conditions, 1904. There are ten good-sized tubers, weighing 3½ pounds. The space occupied by the tubers averaged about ten inches on all sides from the center. In this variety, during the past year, the tubers were distributed all round the stem. In some varieties they tend to form on one side only.

FIG. 6—PLANT OF VERMONT GOLD COIN (SIDE VIEW)

Same plant as in Fig. 5, showing how completely the soil is filled with roots. The tubers were all well below ground, the majority being between two and five inches. The roots extended outward two feet from the centre of the plant, and downward to a depth of over three feet. Observe the potato bug about seven inches below the surface. It was uncovered at this place.

a depth of two and a half feet. The deep-growing roots are very tender and brittle and easily broken, differing in this respect from corn roots. The horizontal roots send out vertical branches, which often descend to a depth of two feet or more.

Shallow tillage, such as hand-hoeing without hilling, retains all the roots. Moderately deep tillage with a five-tooth single horse-cultivator and slight hilling destroys practically all the surface roots, and undoubtedly interferes seriously with the plant's development; while with deep tillage nearly all the long horizontal roots are destroyed, and with them all their numerous vertical branch-roots with their intricate system of fibres and root hairs, by which the potato receives its food. In very heavy soils it may be wise to plant potatoes shallow and then hill them, but in most soils it is better policy to plow deep, plant fairly deep, and give shallow flat cultivation. With deep tillage the roots nearest the surface were at a depth of seven inches, while in the case of those receiving shallow tillage the bulk of the horizontal roots were in the surface seven inches. The hilling covers the potatoes and prevents them from sunburning, and this seems to be all the benefit received. The loss of roots is very hurtful, and takes place at a time when the plant can least afford to suffer injury. Experiments conducted at Vermont Experiment Station[1] show that during the last weeks of growth the weekly increase in weight of tubers is at its maximum, and that checks when the tubers are approaching maturity depress the yield correspondingly.

[1] Ver. Bul. 72, p. 5.

A sample of Early Ohio potatoes taken ninety days after planting, when the vines were beginning to die and the tubers were nearly ripe, showed that the roots penetrated to a depth of over two and a half feet.[1] The branches from the main lateral roots had reached about as deep as those immediately under the hill, and the soil was filled with roots to a depth of about two and a half feet. The system of rooting is similar to that of corn, but the plant is not so good a forager, and the roots do not fill the soil so completely; hence, plants can be placed closer together.

Late varieties have a similar root system, but root more freely, more deeply (a depth of three and a half feet being common if the soil conditions will permit), and occupy the ground more completely; hence, require more room than early varieties.

At Cornell University, during 1904, many potatoes had horizontal roots in the surface inch of soil. All of these would be *destroyed by moderately deep tillage.*

Influence of Depth of Planting on Roots.—Generally speaking, the new potatoes and the roots start out above the seed, although if an under eye of the potato produces the shoot the roots and tubers may develop at the side of the seed. Depth of planting has some influence on the depth at which the tubers will form, and may have some on the roots. The question deserves investigation. Many plants prefer to send out their roots at a uniform depth below the surface: thus, at Cornell University, wheat, whether planted six inches deep or one inch deep, will send out its per-

[1] N. Dak. Bul. 43, p. 544.

manent roots about one and a half inches below the surface.

Blossoming, Tuber Formation, and Hilling.—Potatoes are hilled about the time they come into bloom, and this is the time that tuber formation is beginning. The ancestral type of potato developed seed about this time and died; the tendency acquired by cultivation is to throw all the reserve material into tuber production. These reproductive processes cause a severe drain upon the plant's energies, and the fortnight immediately following the blossoming period is therefore a peculiarly critical time for the plant, during which time its life hangs in the balance. At this time it is subject to extreme heat, and may be injured; also insects, fungi, etc., may attack it, and, to add to its troubles, cutting off a lot of its roots, either just before or about this time, is no doubt the common cause of a decline from which the plant never recovers. Even tuber formation, without the influence of other agencies, may cause a plant to die. The importance of studying the condition of the plant at this time will be appreciated when it is remembered that the entire crop of salable tubers is formed after this critical period is past, and full success with the crop depends upon retaining the plant healthy for from one to three months after the blossoming period. During August, in one case,[1] the crop of potatoes increased at the rate of over 50 bushels, or over 3,000 pounds, weekly per acre. The importance of avoiding checking growth preparatory to or during such a time is evident.

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[1] Ver. Bul. 72, p. 5.

CHAPTER III

SOILS

THE soil considered best is a deep, mellow, free-working loam, grading either to a sandy loam or clay loam, although the crop may be raised on lighter or heavier soils, provided the latter are drained. Tile drainage should be resorted to, if necessary, to reduce the water table to from 3 feet 6 inches to 4 feet below the surface.

Some reasons for selecting a light, sandy, or gravelly loam for the crop are:

1. Such soils can be worked early in spring, and gotten ready for early planting, if desired;
2. The lighter soil becomes warm more readily in the spring than a heavier soil, and germination of the tuber and growth of the plant proceeds more rapidly;
3. They can be easily worked, and placed and maintained in good tilth without a heavy labor bill;
4. The effects of the manures and fertilizers applied are generally perceptible for a longer period of time than on lighter soils;
5. The potatoes grown on such a soil usually come out bright and clean, smooth and of more uniform size — important factors when they go on the market;

6. Light soils usually produce potatoes of better quality, because they tend to shorten the growing period by cutting off the moisture supply, and thus forcing the potatoes to mature earlier;
7. Those grown on well-drained sandy loam soils usually keep better than those grown on stiff clay soils.

Aroostock County, Maine, is famous for its potatoes.[1] Its soil presents a gently rolling surface, and is composed essentially of drift deposited during the melting of the ice after the ice age, and resting on a stratum of limestone, which in many places comes to the surface. The soil partakes of the general nature of drift containing a considerable portion of sand and the usual amount of organic matter. It is peculiarly suited to potatoes, because it does not pack after hard rains nor during periods of drouth. Its open and porous nature permits the free development of tubers and the ramification of the roots. The soil was originally covered with a growth of hard and soft woods, consisting chiefly of maple, cedar, birch, white poplar, spruce, hemlock, and pine. The forest growth was dense, and in clearing large quantities of ashes were produced, which fitted the virgin fields particularly for the production of large crops of potatoes. After a few years of cultivation, the crop-producing power of the soil showed a diminution, and to-day applications of farm manures and commercial fertilizers containing a large percentage of potash are resorted to. Analyses of Maine soils show that they are silicious, contain considerable or-

[1] U. S. D. A., Div. of Chemistry, Bul. 58, p. 5-8.

ganic matter, and are reasonably rich in lime and magnesia, which seem to be essential constituents of a soil suited to the growth of potatoes. The potash is also in fair quantity, but not sufficient to produce maximum crops. The famous potato-growing counties of Wisconsin, Portage, Waushara, and Waupaca had over 60,000 acres in potatoes in 1899, and these are as important to the Central States as Aroostock County, Maine, is to the Eastern States. The soil is glacial drift, some of it being made up of level deposits of sand and gravel covered with a light loam. The sand is usually underdrained by a bed of coarse gravel. Sandy loams prevail. Clayey loams occupy some areas, but are not prevalent. The average yield is 100 bushels per acre.

On Long Island, N. Y., the chief potato soils on the south side of the island are light silt loams underlain either by gravel or sand, while gravelly till is the main type on the northern side. The yields vary from 80 to 250 bushels per acre.

The Influence of Soil on Different Varieties.—Professor Buffum,[1] of Wyoming Experiment Station, reported on eight varieties grown on each of two kinds of soil represented on the experiment farm. The soil and crops were treated alike. Plat 1 is bench-land above the river, and is a deep red colluvial soil containing little humus. Plat 2 is bottom-land next the river, and is a black soil containing a large amount of humus.

[1] Wyo. Bul. 32, p. 6.

TABLE I

VARIETY	*Plat 1 Yield per acre*	*Plat 2 Yield per acre*	*Increased yield on Plat 2*
	Lbs.	*Lbs.*	*Lbs.*
Beauty of Hebron	9,678	23,628	13,950
Early Mayflower	15,060	28,842	13,782
Early Puritan	12,702	32,340	19,638
Empire State	15,372	22,698	7,326
Late Puritan	18,858	26,742	7,884
Pride of the West	5,040	23,322	18,282
Snowdrop	14,562	25,500	10,938
White Elephant	11,808	27,990	16,182
Average	12,885	26,383	13,498

The figures taken collectively show the importance of selecting a soil suitable for the crop to be grown, the yield being doubled on Plat 2, while taken individually it is evident that certain varieties were better adapted to the environment than others. The question of which variety will best suit the environment must be determined by the grower.

Subsoiling.—Buffum[1], of Wyoming, states that subsoiling may be recommended throughout that State for potatoes. The cost of subsoiling to a depth of 16 inches to 18 inches varied between $3.00 and $6.00 per acre. Hays[2], of Minnesota, found it to be expensive and not profitable under most conditions in that State, and that it reduced the yields of crops on land already sufficiently open and porous. In humid climates, if attempted, it is advocated that subsoiling be done in the fall, to permit the readjustment of the soil granules before springtime, so that the moisture will be able to rise upward from the subsoil, as evaporation takes

[1] Wyo. Bul. 41, pp. 20, 21; Bul. 32, pp. 7, 8. [2] Minn. Bul. 68, p. 609.

place at the surface, and prevent the crop being destroyed by lack of moisture. Injurious results from subsoiling in spring have been noted, probably due to the working of the subsoil when it was too wet. It does not follow that because the surface soil to the depth of eight inches is dry enough to plow the subsoil will be, and in many cases the subsoil has been puddled by spring working, and the supply of moisture from below more or less completely cut off, with disastrous results to the crop.

Preparation of the Soil.—The ideal crop to precede potatoes is timber, but as no rotation comprising this crop is in use, the preparation given after timber demands little attention. Potatoes are more commonly grown after potatoes, corn, or after clover or sod. In such cases preference is usually given to fall plowing, accomplished during October or November until freezing prevents further work. Deep plowing should be done in fall, because opportunity is then given for the storage of water in the soil during the winter and when the thaw occurs in spring. If manure is to be applied it is spread before plowing, but, if rotted, it may be applied later and disked in. The depth of plowing varies with the soil, probably six inches or eight inches being most common, although, if the soil will permit, eight inches to twelve inches will be better. When soils are deficient in humus, it is generally inadvisable to plow deeply. The humus content of such soils should be increased and the depth of plowing increased correspondingly, thus bringing the land into a higher state of production. In some districts where the snow covers the ground all winter the land is harrowed well

in fall and left nearly ready for planting, thus facilitating spring work. Where the frost penetrates deeply, or the soil is apt to run together, the land is better left rough plowed all winter and fitted in spring; but this entails some loss of time, and prevents the early planting of potatoes.

Sometimes it is necessary to plow in spring, and in many cases it is profitable to replow when a fall plow-

FIG. 7—A USEFUL TYPE OF SPRING-TOOTHED HARROW

ing has been given. Under such conditions a depth of not more than six inches or eight inches is advised, because plowing land is attended by loss of moisture, and in most cases the amount of moisture held in the soil or supplied as rainfall during the growing period is insufficient to insure maximum yields; hence, care should be taken to conserve all the moisture possible by plowing judiciously, making and maintaining a mulch of the surface soil, thus checking evaporation,

and by enriching the soil in humus either by manuring or a suitable rotation. Humus affects the physical properties of the soil considerably—among other things, enabling it to hold more moisture without injury to the plants in a wet time, and to endure drouth in a

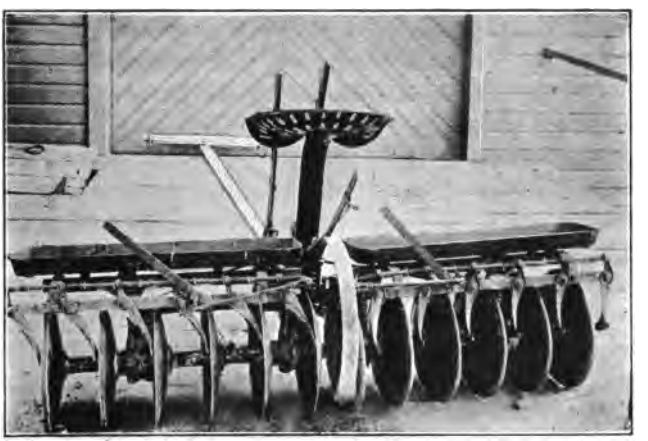

FIG. 8—AN EFFICIENT PULVERIZER: THE DISK HARROW

dry time.[1] Even where irrigation is practiced the above factors cannot be economically neglected.

Surface-fitting Tools.—The Acme harrow is one of the best tools for making a soil mulch before the crop is planted, and in trials made by Sanborn[2] was shown to be the most efficient type of harrow for pulverizing soil. On stony land, or where roots of trees interfere, the spring-tooth harrow (Fig. 7) is preferred for deep tillage of the soil, while under other conditions

[1] Minn. Bul. 68, pp. 576–579. [2] Utah Bul. 4.

the disk harrow. These tools work deeper than the Acme harrow, and may be used to prepare the soil to a depth of four to six inches, which seems to be as deep as is necessary. Few farmers prepare land to this depth, as it requires three horses on a six-foot harrow on a loam soil. Two to 2½ inches is more common. Harrows differ in their action; thus, the spring-toothed harrow

FIG. 9—DOUBLE-ACTION CUTAWAY HARROW

and the smoothing or spike-tooth harrow tend to compact the soil while fining it, while the disk type (Figs. 8 and 9) and Acme harrows tend to lighten it and make it more open when they fine it. For potatoes and corn the latter are preferable, while for wheat the former. Whatever tool is used the land should be well fitted. Few farmers prepare the land well enough, and many

would find it more economical and profitable to spend another week working the land than to rush the crop into a badly prepared seed-bed. The soil under the plants and near them cannot be touched when they have been planted, while wide tools may be used before.

CHAPTER IV

ROTATION

In some cases potatoes are grown continuously for several years on the same soil, but a rotation of crops is preferable for many reasons—among others, to lessen the dangers of attacks of diseases and insects, and to bring the soil into a suitable physical condition for growing this crop. Some rotations suggested by Wheeler, of the Rhode Island Experiment Station,[1] are as follows: three-year rotation—potatoes, winter rye, common red clover; four-year rotation—corn on clover sod, potatoes, winter rye, clover. This can be made into a five-year rotation by seeding timothy and redtop with the clover, and leaving the mixture down two years, thus reducing the labor bill to some extent. Trials of these and other rotations were made on land so poor that corn attained a hight of but 4 or 5 inches, while the first crops of salable potatoes were but 65 bushels per acre. During later years, with management similar to that given the first year, and the application of a similar amount of fertilizers, the yields ran up to 350 bushels of salable potatoes per acre. A common Maine rotation is a four-year course of potatoes, oats, clover and grass, the latter for two years—it being noted that clover thrives on good potato land. In deciding upon the rotation it is important

[1] R. I. Bul. 74, 75, 76.

to note the influence of each crop upon the moisture content of the soil (see p. 50); thus, rye removes less moisture from the soil than wheat. Oats draw heavily upon the moisture content.

The potato crop is not usually considered to be a heavy water consumer. It leaves the soil in a relatively moist condition; hence, the wisdom of the Maine four-year course, in which oats succeed potatoes. This course requires but one deep plowing in four years, that for the potatoes, and in this it is economical. Peas use a relatively small amount of water, and would leave the soil in good shape for potatoes. In Wisconsin,[1] while potatoes grown in rotation yielded 342.8 bushels per acre, a crop grown on an old alfalfa sod yielded but 277.7 bushels per acre, although the rainfall was considered adequate to produce a full crop. In some cases clover tends to leave the soil drier than some other crops, and its use as the preceding crop for potatoes may be detrimental. In most cases, however, a leguminous crop is the best to precede potatoes. In Florida[2] cow-peas preceding potatoes increased the yield 40 per cent. The Ohio Station[3] found that in the three-course rotation—potatoes, wheat, clover—whenever good crops of clover were grown the economy of using nitrogenous fertilizers for the potatoes was questionable, thus showing that a good rotation is equivalent to manuring. Plowing under a leguminous crop is held to be good practice on farms where an adequate supply of manure is not forthcoming and little stock is kept; thus, at the

[1] Wis. Report, 1902, p. 188.
[2] Fla. Report, 1900-1901, p. 28.
[3] Ohio Bul. 125, p. 132.

Maryland Station,[1] plowing under a crop of crimson clover increased the yield 34.4 bushels per acre, or 50 per cent., and the average gain for two years was 27 bushels per acre, or 45 per cent.; the Storrs[2] (Connecticut) Station reports that clover sown in corn at the last cultivation had a high value when used to plow under as manure for potatoes, even though it only attained a hight of three or four inches; in Germany[3] the sweet clover (*Melilotus alba*) is found to be a valuable green manure; while in another German experiment,[4] where clover was seeded in rye which was grown for grain, the clover being plowed under the following spring, it was noted that the yield of rye was dimished, but the yield of the succeeding crop of potatoes was increased. The yields of rye and potatoes were:

TABLE II

CROP	*Yield per acre of rye*, 1892		*Yield per acre of potatoes*, 1893	
	Bushels	*Lbs.*	*Bushels*	*Lbs.*
Rye alone	14	44	289	35
Rye alone	15	21	296	15
Rye and late sown red clover	13	50	330	25
Rye and early sown red clover	12	35	430	39

As green manuring for poor sandy land on Long Island, N. Y., Professor Stone, of Cornell University, suggested sowing a bushel of cow-peas and ten pounds of crimson clover per acre, in July, with some fertil-

[1] Md. Bul. 38, p. 58.
[2] Conn. (Storrs) Report, 1900, p. 65.
[3] E. S. R., V., p. 701.
[4] E. S. R., VI., p. 292.

izers. The cow-peas were killed by the first frost, but the clover persisted; the crowding, however, was such that the plants of neither crop got too large before being plowed under the following spring. For farther north a combination of half a bushel of buckwheat and a peck to half a bushel of rye per acre, sown together, has given good results. Rape sown at the rate of four to five pounds per acre is useful. Other crops will suggest themselves. In parts of New York, especially on heavy loams, buckwheat is esteemed as the preceding crop for potatoes. It crowds out weeds and leaves the soil in excellent physical condition.

CHAPTER V

MANURING AND FERTILIZING

LAND is manured and fertilized either to increase or to maintain its crop-producing power. Whether this is secured by the direct effect of the chemical ingredients in the manure or fertilizers, or by their influence upon the physical properties of the soil, or both, is an unsettled scientific problem, but all agree that under certain conditions the addition of manures, fertilizers, and water to the soil is profitable. Whether it will be profitable on a particular farm or field, and the manure, fertilizer or combination of fertilizers which will be most profitable to use, are questions the grower must settle for himself by trial. No chemical examination of the soil yet conducted has shown why two soils, apparently identical in chemical composition, should not produce similar yields of crops. Experience has shown that the chemical composition of the soil is no guide to its crop-producing power. Hence, all that can be given in this chapter is to submit mixtures of fertilizers that are used and the rôle the different important ingredients are believed to play in the plant economy.

In addition to water, which is treated elsewhere, four elements are frequently applied in various chemical forms as fertilizers—nitrogen, phosphorus, potassium, and calcium. The potato through its life requires liberal supplies of the first three of these elements, and its behavior in regard to these is similar to that of

a shallow-rooted root crop. The facts that the potato is a starch-producing crop, and that its period of growth is through the summer and extending well into autumn must be remembered. In these features it is similar to corn, but distinctly different from the cereals which ripen in the summer, as it is assumed that it is able to utilize the nitrates and other plant-food liberated during the summer and fall. E. Hecke[1] states that the demand for nitrogen is especially strong during the first half of the vegetative period, while the demand for potash is greatest during the second half of the growing period, and that potash aids in the formation of starch, and especially in the development of tubers and roots, although the effects were observed in all parts of the plant.

The Influence of Nitrogen.—Wilfarth[2] showed that when the supply of nitrogen is insufficient the leaves tend to turn yellow, and that if the available supply of potash is deficient heavy applications of nitrogen tend to reduce the percentage of tubers and starch. Lawes and Gilbert[3] show that nitrogen stimulates the production of starch, provided the mineral constituents are not deficient; but in large quantities nitrogenous fertilizers stimulated luxuriant growth, delayed maturation, and produced potatoes richer in nitrogen and much more liable to disease. At the Rhode Island Experiment Station[4] dried blood ranked first of the nitrogenous fertilizers applied, followed by nitrate of soda and sulphate of ammonia; but on soils said to be extremely acid, dried blood was only about half as

[1] E. S. R., VII., p. 667.
[2] E. S. R. XIV., p. 561.
[3] Rothamsted Memoirs, Vol. VI.
[4] R. I. Bul. 65, pp. 133, 134.

beneficial as it should be; hence, such soils need liming before full benefit can be derived from the use of this fertilizer. A mixture of two-thirds dried blood and one-third nitrate of soda, or of equal parts of all three fertilizers, is suggested. At the Tennessee Experiment Station[1] cottonseed-meal was found to be a more profitable source of nitrogen than nitrate of soda, while at the Florida Station[2] the nitrogen of cottonseed-meal and castor pomace were equally effective, but that of nitrate of soda was more so by 30 per cent.

The Influence of Potash.—Wilfarth and Wimmer[3] show that when potassic fertilizers are applied to a soil almost destitute in potash they—

1. Increase the size of the tuber, but have little influence upon its composition, and that the amount of potash in tubers remains fairly constant, uninfluenced by the amounts in the soil, or applied, unless very heavy applications are made, which may cause an increase to a certain point, but will be attended by a decline if continued.
2. Decrease the percentage of stems and leaves, but have no marked influence on the roots of potatoes.
3. Have a marked influence on the shape and appearance of the leaf; if deficient, the leaves are yellowish-brown in color, and become spotted or striped in the portions between the veins, while the petiole of the leaf and ribs retain their dark green color. If the supply of potash is insufficient the leaves tend to curl, and sometimes collapse of the plant follows.

[1] Tenn. Bul., Vol. XIII., No. 3, p. 6.
[2] Fla. Report, 1900-1901, p. 27.
[3] E. S. R., XIV., p. 561.

4. Increase the quantity of water transpired per gram of dry matter.

Hecke[1] shows that the application of potassic fertilizers has a marked influence in the production of tubers and roots, and that potash assists in the formation of starch. Lawes and Gilbert[2] noted that the percentage of potash was relatively high when the supply of it was relatively liberal and *vice versa*, but the variations are small, and that where there was a deficiency of potash in the supply and in the ash there was generally an increased supply of lime in the ash.

Which is the Better Source of Potash, Sulphate or Muriate of Potash?—This question is still unsettled, because, apart from other considerations, one of the deciding factors is the relative cost of each. In many cases the results are inconclusive,[3] while in some cases[4] the fertilizers appear to be of equal value. In others[5] sulphate of potash gave better results; thus Davidson, of Virginia,[6] found that the potatoes grown by sulphate of potash contained more dry matter but a less percentage of starch than those fertilized with muriate of potash. Brooks[7] found that sulphate of potash gave a greater yield per acre of merchantable tubers, which were of larger size and of superior eating quality, containing 2 to 3 per cent. more starch, and, when cooked, the potatoes were whiter, of better flavor, and more mealy.

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[1] E. S. R., VII., p. 667. [2] Rothamsted Memoirs, Vol. VI., "Experiments on the Growth of Potatoes." [3] (N.Y.) Geneva Bul. 137, pp. 604, 620. [4] N. H. Bul. 41, p. 13. [5] Mass. (Hatch) Report, 1896, p. 22; R. I. Bul. 65, p. 133; Mich. Bul. 131, p. 10; (N. Y.) Geneva, Bul. 137, pp. 621, 622. [6] Va. Bul. 92, pp. 107, 108. [7] Mass. (Hatch) Report, 1904, p. 122.

The time and method of application must be considered. In my experience muriate of potash has given better results when applied the previous fall, especially if more than 100 pounds per acre are to be applied, the presumption being that the potassium compound undergoes changes in the soil, and that the injurious chlorine is removed as a chloride by the winter and spring rains. For spring application in the drills sulphate of potash may be better, or a mixture of sulphate and muriate of potash, if more than the above-mentioned quantity is required. The disadvantage of the muriate of potash seems to be due to the fact that it is a chloride, and Sjollema[1] and Pfeiffer[2] have shown that the chlorides of potassium, sodium (common salt), and magnesium, when added to the sulphate of potash, diminished the starch content of the potatoes considerably, and that the reduction was greatest in varieties rich in starch. This would seem to support the common idea that sulphate of potash produces better quality potatoes than muriate of potash. Wheeler,[3] of Rhode Island, shows that calcium chloride had a marked poisonous effect upon potatoes and nearly destroyed them, while the same amount of calcium in certain forms other than the chloride or sulphate increased the yield and vigor of the plants. New varieties, and those making a heavy growth of haulm, seem to be particularly sensitive to chlorides.

Influence of Phosphoric Acid.—Lack of phosphoric acid is accompanied by dark green leaves. While phosphoric acid aids starch formation, it is often re-

[1] E. S. R., XII., 434. [2] E. S. R., XII., 443. [3] R. I. Bul. 40, pp. 85, 86.

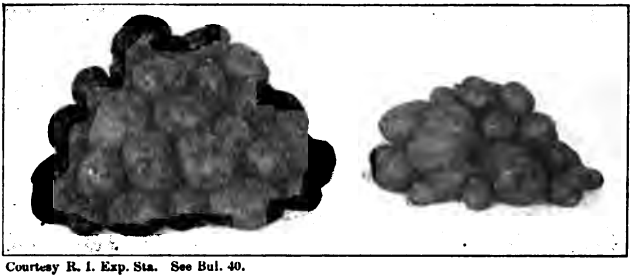
garded as being of less importance than potash. The results obtained at the Ohio Station[1] show that phosphoric acid is the most essential fertilizer for their conditions, some potash, and, in some cases, nitrogen, being also required. I found the same to be true at Briarcliff Manor, N. Y., where 100 pounds of available phosphoric acid per acre (equal to 600 pounds acid phosphate, 16-17 per cent. available) gave profitable returns. My own observations are that an excessive application of available phosphoric acid has a marked influence upon the foliage, causing it to be small, dark green, wrinkled, and apparently stunted in development, with consequently early maturity. In some cases the period of growth is reduced six or eight weeks, and consequently the yield is low; but, owing to the potatoes being mature, the quality is generally good. In certain localities, for early potatoes, where it is desirable to hasten maturity, the use of fair quantities of acid phosphate, with a limited supply of nitrogen and potash and no barn manure, is found to be good practice. The nitrogen may be supplied in an available form as nitrate of soda, since nitrification may not be active in the soil during the early period of growth.

The Influence of Calcium.—Calcium does not appear to be so important as some of the other elements, although in some cases it produces a marked increase in yield (Fig. 10). If applied in a form which has an alkaline action upon the soil—as, carbonate of lime or quicklime—it may have an injurious effect by

[1] Ohio Bul. 125, pp. 131, 132.

producing conditions which aid the development of scab.

Barn Manure.—Applying barn manures is commonly practiced for potatoes with profitable results. Lawes and Gilbert[1] showed that only a small portion of the nitrogen of farm manures is taken up by the crop; thus, with an annual manuring of 15.5 tons per acre, containing 200 pounds of nitrogen, continued for twelve



Courtesy R. I. Exp. Sta. See Bul. 40.

FIG. 10—INFLUENCE OF LIME UPON POTATOES

Showing the influence of lime upon the yield, and that it increases the percentage of scabbed potatoes. *Right*, unlimed. *Left*, limed. Other fertilizers the same in both cases.

years, but 8.3 per cent. of the nitrogen was recovered in the crop. "These results seem to indicate that this crop is able to avail itself of a less proportion of the nitrogen of the manure than any other farm crop. Yet, in ordinary practice, farm-yard manure is not only largely relied upon for potatoes, but is often applied in larger quantities for them than for any other crop." Taft,[2] of Michigan, found that twenty-four loads of manure per acre gave the largest yield, while at the

[1] Rothamsted Memoirs, Vol. VI. [2] Mich. Bul. 131, p. 10.

Wisconsin Experiment Station twenty loads per acre were applied, and larger quantities in Great Britan.

It seems natural to assume that the beneficial effects of manure must largely be due to other causes than the addition of plant-food. Among these may be its influence on the physical properties of the soil, rendering it more retentive of moisture, more porous and more permeable for air and roots, and a better home for the useful soil bacteria, which, in fact, it may supply. The decomposition of such quantities of organic matter, with the consequent liberation of carbon dioxid, aids in rendering the mineral resources of the soil more available. Generally speaking, it is more economical to apply about ten tons of manure per acre and supplement it with fertilizers, except upon loose open soils of poor texture, where the beneficial effect from the larger amount should probably be ascribed to its influence upon the retention of moisture. It is preferable that the manure be rotted somewhat and applied the previous fall, while the fertilizers may be applied when planting. On some soils, to reduce the danger of disease, it may be advisable to apply all the barn manure to the previous crop. The application of fertilizers is profitable under most conditions in the Eastern and North Central States. At New Hampshire Experiment Station the application of fifteen cords of manure increased the yield of marketable potatoes over 100 bushels per acre compared with no manure, and the use of 1,500 pounds of fertilizers with the same amount of manure resulted in a further increase in yield of 130 bushels per acre.[1] Taft,[2] of Michigan, shows that

[1] N. H. Bul. 111, p. 116. [2] Mich. Bul. 131, p. 10.

the average gain from the use of a full application of fertilizers was eighty bushels per acre. In Long Island, N. Y., a fertilizer mixture containing 4 per cent. nitrogen, 8 per cent. available phosphoric acid, and 10 per cent. potash has proven satisfactory. It is used in amounts varying from 500 pounds to 2,000 pounds per acre, and in many cases more potash is applied than is profitable. The use of 1,000 pounds of this fertilizer has given the greatest profit. Where 1,500 pounds or 2,000 pounds were used the cost of the fertilizer was more than the market value of the increased yield of potatoes. For some years I have used a mixture of 100 pounds sulphate of ammonia, 400 to 600 pounds acid phosphate (16 to 17 per cent. available), and 100 pounds muriate of potash with eight to ten tons of partially rotted manure per acre on a medium loam soil. At New Hampshire Experiment Station[1] 300 pounds muriate of potash per acre gave the best results when compared with none, 150 pounds, and 450 pounds per acre.

The above mixtures merely show quantities used by certain individuals; each farmer must work out a mixture suited to his needs. There are other conditions than the application of fertilizers. As Dr. W. H. Jordan[2] pithily puts it: "It is clearly evident that a large supply of plant-food does not necessarily insure a satisfactory crop. Other conditions which largely pertain to culture—such as texture, humus, and water-supply—exercise a controlling influence, and when these conditions are unfavorable their effect is not overcome by heavy applications of fertilizer."

[1] N. H. Bul. 111, p. 115. [2] (N. Y.) Geneva Bul. 187, p. 215.

It almost invariably occurs that potatoes grown without any manure mature earlier and contain more dry matter, with a correspondingly reduced yield,[1] than those grown on land manured with barn manures or a complete fertilizer. The vigorous growth induced under the latter conditions cannot be matured in the same time, hence for an early crop it is unwise to stimulate too vigorous growth.

The Function of Fertilizers.—The prevailing opinion in purchasing fertilizers is that they contain a certain amount of plant-food—usually nitrogen, phosphoric acid, or potash—in a more or less available form, and that the benefits received from their application is due to the addition of this plant-food to the soil. So deeply seated is this theory that all fertilizers are bought and sold on this basis, and laws controlling the business have been formulated upon it. The ingredients—nitrogen, phosphoric acid, and potash, with others—are necessary for the growth of all crops, but the amounts of the essential ingredients, other than the above mentioned, are believed to be present in the soil in sufficient quantities to meet all the requirements of the crops grown.

A 300-bushel crop of potatoes has been found to contain 81 pounds of nitrogen, 30.6 pounds of phosphoric acid, and 79 pounds of potash. Taking 49 New York soils, the chemist found that the surface eight inches contained, per acre :[2]

Nitrogen . . .	3,053 pounds,	enough for	38 crops
Phosphoric acid,	4,219 "	" "	137 "
Potash	16,317 "	" "	207 "

[1] Va. Bul. 92, p. 107.

[2] (N. Y.) Cornell Bul. 130, p. 157.

Upon such soils as these applications of fertilizers containing phosphoric acid, and, in some cases, potash, have been found, by experience, to be most profitable—a condition of affairs which could never be ascertained from the analyses. It is seldom that the increase in yield of crop bears any relationship to the quantity of the fertilizers applied. Without either fertilizers or manure, but given good tillage, yields of 300 bushels of potatoes per acre have been obtained for four successive years on the same piece of land.[1]

The amount of plant-food removed by any crop is small, and is obtained from all parts of the soil wherever roots extend. Most soils contain certain sufficient plant-food to supply the demands of any crop grown thereon for an indefinite period of time. To maintain crop production at a profitable point, attention must be paid to factors other than the supply of plant-food.

The ingredients applied as fertilizers will, no doubt, be found to have a value other than their value as carriers of plant-food. Their value for this purpose may be found to be small, while the benefits derived from their use may be found to be largely due to their chemical action upon the soil—*e.g.*, as sanitary agents, promoters of the growth of desirable organisms or destroyers of injurious ones, aids in the formation of desirable chemical compounds in the soil or neutralizers of undesirable compounds, to their influence as stimulants, and upon the physical properties of the soil. That their use is desirable in some cases is evident. Why it should be, and how, are matters for investigation.

[1] (N. Y.) Cornell Bul. 191, p. 192.

The farmer needs to realize that the soil on his fields to-day is not the same as that of last year. Soil is changing. The subsoil of yesterday is the soil of to-day. Although the amount removed by crops is so small that it is a negligable quantity, that removed by washing and by the wind is enormous. The muddy stream, the bars at the mouths of rivers, the movement of soils by the wind, and even the dust-cloud raised when harrowing, show that far more plant-food is removed in these ways than in crops, and to check these leaks is of more importance than to try to make up the loss by the addition of plant-food. The maintenance of a satisfactory amount of organic matter in the soil in a proper condition may usually be accomplished by a judicious rotation of crops, manuring, and liming.

"The old method has been to feed crops with commercial fertilizers, the new agriculture looks to nature for its sources of plant-food. These sources are (1) the large stores of unavailable plant-food in all soils, (2) the unlimited stores of nitrogen present in the air."[1] Research has revealed the fact that soil organisms can take plant-food from both of the above sources and furnish it to growing crops, and that a fertile soil is one in which these processes are going on at the highest rate, and that it is necessary to stimulate these biological activities. Humus is a food for these organisms. Lime is essential for maintaining the soil in a slightly alkaline condition, and for fixing some of the compounds formed in the soil; and drain-

[1] Del. Bul. 66, p. 14.

age, deep plowing, and thorough tillage are necessary to bring air into the soil and stimulate bacterial activity. Humus, lime, and tillage are three important factors in maintaining a fertile soil,[1] and the farmer who understands the value of these is the one who will derive the most benefit from the use of fertilizers.

Purchasing and Applying Fertilizers.—Fertilizers may be divided into three classes—viz.:

(*a*) Nitrogenous, or those rich in nitrogen.

(*b*) Phosphatic, or those rich in phosphorus.

(*c*) Potassic, or those rich in potassium.

Nitrogen occurs in fertilizers, as:

(1) Nitrates—*e.g.*, nitrate of soda, nitrate of potash.

(2) Ammonium salts—*e.g.*, sulphate of ammonia.

(3) Organic nitrogen—*e.g.*, dried blood, tankage, hoof meal, etc.

Nitrogen as nitrates is immediately available as plant-food, is soluble in water, and if not taken up quickly by plants is liable to be lost in the soil water; hence small quantities applied at short intervals give the best results.

Nitrogen as ammonium salts soon becomes available in warm weather, and is not so liable to be washed out of the soil as when in the form of a nitrate.

Nitrogen as organic matter is more slowly available.

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[1] Del. Bul. 66, "Soil Bacteria and Nitrogen Assimilation."

Phosphorus occurs in fertilizers, as:

(1) Insoluble phosphate of lime—*e.g.*, floats, bone meal, tankage.

(2) Soluble phosphate of lime—*e.g.*, acid phosphate, dissolved bone.

Insoluble phosphate of lime is considered to be but slowly available. It is converted into "soluble" by treating it with an acid, usually sulphuric acid.

Soluble phosphate of lime, as a rule, is more active than insoluble in promoting plant growth, but on acid soils insoluble phosphate often gives better returns. The soluble phosphate of lime and a phosphate soluble in weak acids constitute the "available phosphoric acid" of the chemist.

Potassium is the valuable ingredient found in:

Wood ashes, kainit, sulphate of potash, double salts, and muriate of potash.

It usually gives good returns when applied to light, sandy, and peaty soils. As kainit contains chlorides and muriate of potash is a chloride, it is often advisable to apply them some time previous to planting the crop, in order that the injurious substances may be removed by the soil water, chlorides, in excess, being injurious to potatoes.

Value.—All fertilizers may be valued according to the percentage of nitrogen, soluble phosphate of lime, insoluble phosphate of lime, and potash present. They are often valued on the unit system. A unit is one per cent. of a ton, or 20 pounds; the ton, 2,000 pounds.

Unit Value.—In order to find the unit value of the different ingredients, divide the price per ton of the fertilizer by the percentage, or number, of units of the various valuable ingredients; this will give the cost per unit. For example, if sulphate of ammonia be $66.00 per ton and contains 20 per cent. of nitrogen, then $66 \div 20 = 3.30$ per unit (see Table, p. 45).

If the price per pound be desired, divide the price per unit by 20, or the number of pounds in the unit; thus, $3.30 \div 20 = 16.5$ cents per pound.

For a fertilizer containing several ingredients, find the lowest cost of each ingredient in a standard fertilizer—as, nitrate of soda for nitrogen, muriate of potash for potash, and acid phosphate for soluble phosphoric acid—and compare it with these.

Purchasing Fertilizers.—In purchasing fertilizers it is advisable to write for quotations with guaranteed analyses, ascertain, as indicated above, the cheapest source of the valuable ingredients, and then purchase.

The fertilizer containing a unit of plant-food at the lowest cost is generally the one to buy. In figuring the cost always include the freight, cost of hauling, and handling; for instance, one ton of muriate of potash contains as much potash as four tons of kainit, hence the potash as muriate of potash costs only one-quarter as much for haulage and handling. The same applies to high grade acid phosphate and low grade, and unless the filler is of some particular value it is wise to take the high grade or concentrated goods.

Barn Manure.—When not applied to the fields as soon as made, it should be stored under cover and the excrete from the various farm animals mixed,

TABLE III

SHOWING THE COST OF THE DIFFERENT INGREDIENTS IN CERTAIN FERTILIZERS DURING 1904

NAME OF FERTILIZER	VALUABLE INGREDIENTS				COST		
	Percentage of Nitrogen	*Percentage of Soluble Phosphoric Acid*	*Percentage of Insoluble Phosphoric Acid*	*Percentage of Potash*	*Per Ton*	*Per Unit*	*Per Lb.*
					$	$	*Cts.*
Nitrate of Soda	15.5				44.00	2.84	14.2
Sulphate of Ammonia	20				66.00	3.30	16.5
Dried Blood (high grade)	13				45.00	3.46	17.3
Dried Blood	11				38.00	3.38	16.9
Fresh Bone Meal	4				28.00	2.84	14.2
			22			.76	3.8
Steamed Bone Meal	1.25					2.84	14.2
					26.00		
			28			.80	4 0
Fine Ground Bone Tankage	5					2.84	14.2
					27.00		
			14			.91	4.5
Fine Ground Bone Tankage	7					2.84	14.2
					34.00		
			9			1.57	7 8
Acid Phosphate		13			11.00	.85	4.2
Acid Phosphate		16			15 00	.94	4.7
Acid Phosphate		40			40.00	1.00	5.0
Kainit				12	12.00	1.00	5.0
Double Salts of Potash and Magnesia				26	26.00	1 00	5.0
Sulphate of Potash				48	48.00	1.00	5.0
Muriate of Potash				50	43.00	.86	4.3
Analysis of a ton of well-made Barn Manure	.45					1.42	7.1
			.54		1.10	.38	1.9
				.61		.43	2.1
Another sample of Manure	.63					1.42	7.1
			.14		1.24	.38	1.9
				.67		.43	2.1

when the cold cow and pig manure will tend to prevent excessive loss, by heating, from the horse manure. Young growing animals and those bearing young and giving milk will give poorer excrete than

mature fattening animals. The food and the litter used also affect the value of the manure.

In barn manure the nitrogen, phosphoric acid and potash are slowly available, and are arbitrarily reckoned to be worth half what they would cost in fertilizers. The value of a ton of manure for its physical effect upon soils cannot be expressed in dollars and cents, but in the Eastern States it may be presumed to vary between 50 cents and $1.00 per ton; for while the fertilizing ingredients show a value of about $1.25, the manure often costs, or is valued at, $2.00 per ton.

Mixing Fertilizers.—Fertilizer manufacturers lay great emphasis on the value of proper mixing, and usually charge from $5 to $10 per ton for doing it. For example, a commercial potato manure analyzing nitrogen, 3 per cent., phosphoric acid, 6 per cent., and potash, 10 per cent, costs in New Hampshire[1], in 1904, $36.50 per ton. A fertilizer made up by the station on the same formula was just as satisfactory, and after allowing $1.00 per ton for mixing, it cost $24 per ton, a saving of $8.50 per ton, or using 1,500 pounds per acre = $7.10 per acre.

To compound this fertilizer:

3 per cent. nitrogen = 60 pounds nitrogen in a ton (2,000 pounds).

6 per cent. phosphoric acid = 120 pounds phosphoric acid in a ton.

10 per cent. potash = 200 pounds potash in a ton.

Nitrate of soda will furnish nitrogen for immediate use, and the nitrogen of the sulphate of ammonia will

[1] N. H. Bul. 111., p. 110.

become available later on, hence we may take 23¼ pounds nitrogen in the form of nitrate of soda, and 36¾ pounds in the form of sulphate of ammonia. Cottonseed-meal, dried blood, tankage, etc., might also be used if desired.

	Pounds
Nitrate of soda containing 15½ per cent. nitrogen; to furnish 23¼ pounds nitrogen it requires 150 pounds .	150
Sulphate of ammonia containing 20 per cent. nitrogen; to furnish 36¾ pounds nitrogen, it requires 184 pounds	184
Acid phosphate containing 16 per cent. available phosphoric acid; to furnish 120 pounds phosphoric acid it requires 750 pounds	750
Muriate of Potash containing 50 per cent. potash; to furnish 200 pounds potash it requires 400 pounds .	400
Filling, sand, etc., used to make weight if desired . .	516
	2,000

Unless care be taken in mixing fertilizers loss of valuable ingredients may result.

1. Nitrate of soda and soluble phosphate of lime—as, acid phosphate—must not be mixed and allowed to stand for any length of time, or chemical action will take place, resulting in a loss of nitrogen and phosphoric acid.
2. Do not mix an ammonium salt—as, sulphate of ammonia—with any other fertilizer containing free lime, as the lime will set free the ammonia, which will be lost.
3. Do not mix soluble and insoluble phosphates together.

4. Nitrate of soda is very deliquescent, and if left mixed with other fertilizers is liable to render the whole mass wet and pasty, and so difficult to apply. Cottonseed-meal is a very useful source for part of the nitrogen of mixtures. If it is necessary to hold a quantity of nitrate of soda for a time, it is advisable to empty it out of the bags, as they are liable to ignite spontaneously. When emptied do not leave the bags lying in a heap in the corner of the barn. Store nitrate of soda in a dry place.
5. Kainit is also very deliquescent, and it is the worst potassic fertilizer to use in a mixture on this account. Sulphate or muriate of potash are better for mixtures.

Applying Fertilizers.—When a horse planter is used the fertilizer is usually distributed in the row at the time of planting. The fertilizer may be sown broadcast or in the rows as desired, but it should be incorporated with the soil and not left on top.

Water Requirement.—It has been shown clearly that the available water content of the soil exerts a great influence upon the life of the potato plant, upon its assimilation of plant-food, and upon the yield. At the Wisconsin Experiment Station[1] it was found that when two acre inches of water were added in two irrigations in one case the yield was increased 100 bushels of salable potatoes per acre, thus showing that the right amount of water at the right time is a very important factor in determining the yield. Whitson,[2] of

[1] Wis. Report, 1899, p. 213.

[2] Wis. Report, 1902, p. 190.

Wisconsin, shows that if it is assumed that under the existing climatic conditions of that State 18 inches of rainfall during the growing season is sufficient for potatoes, then, on this basis, there was a shortage of 4 inches or more in ten of the past twenty-one years. In Utah [1] it was noted that the largest yield was obtained from a plat irrigated every eighth day and receiving 14 inches of water, and another year [2] 16.62 inches of water with practically no rain produced a yield of 423 bushels per acre. The importance of water was also shown at the same station,[3] when amounts of water varying between 4.3 inches and 9.45 inches were applied between July 18 and August 6, and the yield increased with the increase in amount of water. At the New Jersey Station[4] irrigation increased the yield 36.4 per cent., while at Wisconsin the increase has been 159.58 [5] bushels per acre over the unirrigated plat, and the average gain per year during the six years—1896–1901—was 83.9 bushels per acre. That some risk must be taken in irrigating heavy soils in a humid climate was demonstrated at Wisconsin.[6] Thus, in one year, while there was an increase of 81.4 bushels per acre from irrigating sandy land, on heavier land the yield was reduced 56 bushels per acre because heavy rain followed the second irrigation.

Corn and potatoes require somewhat similar amounts of water to make one pound of dry matter. The figures of Wilfarth and Wimmer [7] and Whitson [8] are as follows:

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[1] Utah Report, 1893, p. 180.
[2] Utah Bul. 26, p. 14.
[3] Utah Bul. 5.
[4] N. J. Report, 1900, p. 184.
[5] Wis. Report, 1901, p. 198.
[6] Wis. Report, 1900, p. 188.
[7] K. S. R., XIV., p. 561.
[8] Wis. Report, 1902, p. 191.

WATER USED PER POUND OF DRY MATTER

WILFARTH AND WIMMER	*Pounds*
Potatoes	200 to 230
Tobacco	300 to 370
Buckwheat	400
Chicory	400
Mustard	500
Oats	460

WHITSON	*Pounds*
Corn	270
Soy-beans	527
Clover	576
Oats	503

King[1] has shown that the amount of water required to make one pound of dry matter in the tuber and vine of potatoes varied between 272 pounds and 497 pounds during the years 1892–7, while that for oats ranged between 446 and 595 pounds; barley, 375 to 404 pounds; peas, 477; corn, 223 to 398 pounds; clover (first crop), 370 to 582 pounds; clover (second crop), 730 to 983 pounds.

[1] "Irrigation and Drainage." F. H. King.

CHAPTER VI

CONSIDERATIONS OF SEED

Source of Seed.—It is often advised that potatoes be obtained from another soil and from a more northern latitude if vigor and delayed maturity are desired, and from a southern latitude if earliness is sought; but, generally speaking, potatoes bred for a district do better there than elsewhere. Few European varieties of potatoes are worth growing in America, and any introduction requires acclimatization and selection. In England we noted that northern grown Scotch seed did not yield so heavily the first year as the second, and the same was true of Maine grown seed in the Hudson River valley. Brooks,[1] of Massachusetts, and Bishop, of Maryland, report exactly to the contrary, although in a subsequent year Brinkley,[2] at the same station, obtained higher yields from home grown seed. The Rhode Island Station[3] found that varieties which produced large yields gave increasing yields the longer the seed tubers had been home grown, and that those which produced smaller yields gave diminishing yields the longer the seed had been home grown. At Louisiana Station[4] home grown seed was equal to, if not better, than western, or eastern grown or Boston seed. At Georgia Station[5] southern grown seed did

[1] Mass. (Hatch) Report, 1896, pp. 25, 26.
[2] Md. Bul. 17, p. 257.
[3] R. I. Report, 1897, p. 380.
[4] La. Second Series Bul. 4, p. 77.
[5] Ga. Bul. 17, p. 166.

best, and the statement is made that the value of seed depends more upon the care exercised in the selection of the strain than the locality where it is grown. Martinet[1], of France, reports that in several diversified trials seed tubers from higher altitudes gave better yields under all circumstances.

Bailey[2], of Cornell, lodges a criticism against the comparison of northern and southern grown seed. He believes the variations to be due much more to the stock itself—how the plants have been grown and handled in previous years—than to any influence of latitude. He believes it to be impossible to secure stock from different growers which is sufficiently uniform to allow of comparative experimentation. That such variation exists is shown by Brooks'[3] observation on Beauty of Hebron and Early Rose potatoes. Seed potatoes of the same variety obtained from different localities gave a variation in yield of about 50 per cent. for each variety. Probably the matter is one of individuality. It is necessary to study each potato and hill, and perpetuate a variety suited to the particular environment. If this variety possesses the capacity of adapting itself rapidly to other environments it is more useful, but it must be able to grow vigorously and mature its tubers in order to maintain its value. The Ohio Experiment Station[4] found that the selection and storage of potatoes is of more importance than the use of seed grown on other soil. Kansas Experiment Station[5] found that tubers matured in July were the most

[1] E. S. R., XII., p. 636.
[2] (N. Y.) Cornell Bul. 25, p. 175.
[3] Mass. (Hatch) Report 1899, p. 82
[4] Ohio Bul. 76, p. 46.
[5] Kans. Bul. 37, pp. 155, 156.

satisfactory seed for the second crop, and the practice of using first-crop tubers as seed for the second crop is rapidly gaining ground in the South, owing to the difficulty of holding seed over.

Management of Potatoes Previous to Planting.—The best way to hold seed potatoes is in cold storage at a temperature of 33° to 35° F. Should the temperature fall to freezing-point (32° F.) for a short

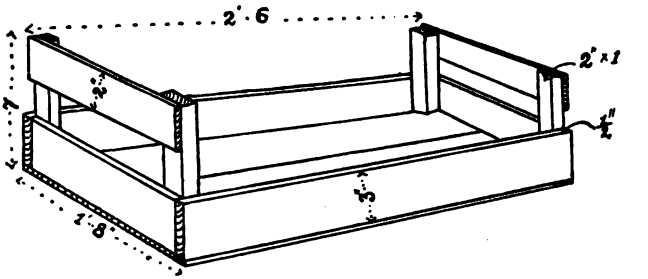

FIG. 11—A USEFUL POTATO TRAY FOR THE STORAGE AND SPROUTING OF SEED POTATOES

For small quantities, a useful size is 24 x 12 inches. This size will hold about forty pounds of tubers, and can be conveniently handled. The larger size holds about eighty pounds of tubers.

time probably no harm will result, as the freezing-point of potatoes is rather lower than that of water. As most farmers do not have cold storage some substitute must be found. A cool, fairly dry cellar, or a root-house, is a very good alternative, or, failing this, the potatoes may be pitted outside and covered so that no frost can reach them (see "Storing"). Several weeks before planting the tubers should be spread out on the barn floor two or three thick, in the light, to quicken growth. Potatoes vary in the time they take

to germinate. Mature potatoes will not begin to grow until they have had a period of rest. In some varieties this may be but a few weeks, while others may be held months before they show signs of growth. In the island of Jersey and the early potato growing districts of the United Kingdom it is customary to store the seed potatoes in flat trays (Fig. 11). The advantages of these are: (1) the seed cannot heat; (2) a large quantity can be stored in a room, the trays being tiered almost to the roof; (3) seed can be easily examined at any time and conveniently moved, hence diseases—as, wet-rot, dry-rot, etc.—are more easily controlled; (4) the potatoes may be sprouted in the trays; (5) the potatoes can be moved to the field in and planted from the trays.

The tray is the best means of storing new varieties which have been purchased or grown in small quantities.

Sprouting Potatoes.—Lavalleé[1] and many others have found that sprouting seed potatoes in a well-lighted room increases the yield and earliness, and produces a more vigorous growth of vines and a larger starch content in the tubers. One explanation offered for the increase in yield is that the short, thick stem developed under the above conditions bears many scales or leaves for its hight, and it is from the axils of these scales, the place where the scale joins the stem, that the tuber-bearing branches are produced (Fig. 12). The more scales produced, the more opportunity for the development of tubers. If the tubers start growth in the dark, either indoors or below

[1] E. S. R., XII., p. 1032.

ground, the scales are formed at longer intervals, and there are correspondingly fewer places for the production of tuber-bearing branches. Also, in the latter

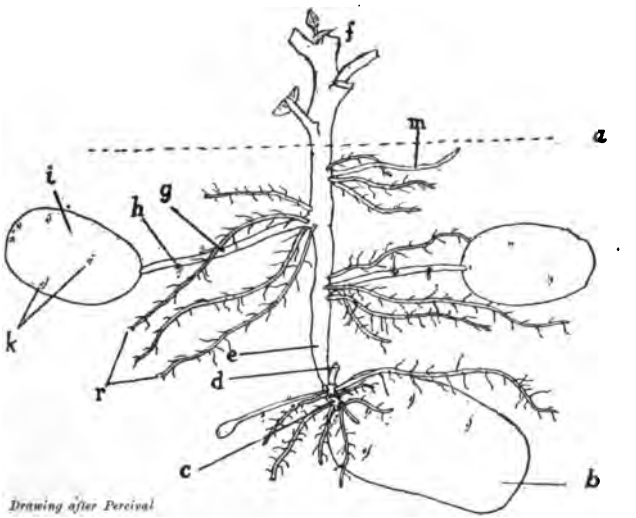

FIG. 12—POTATO PLANTED FOUR INCHES DEEP
(*Diagrammatic*)

a—Ground level. *b*—Seed potato. *c*—Short sprout sent up before planting, which sent up two branches, *d*, *e*; *d* being broken off, and *e* cut off at *f*. *g*—The tuber-bearing stem, or rhizome, which bears buds at *h*, and thickens at the end to form a tuber, *i*, upon which eyes having buds, *k*, may be seen. *m* is a tuber-bearing branch, or rhizome, which has not yet begun to form a tuber, and *r* shows where the roots were broken off. Generally four roots are sent out for each tuber-bearing branch.

case, the leaf-bearing branches produced above ground are weaker. The system is considered essential in the island of Jersey and the early potato growing districts of the United Kingdom, and is practiced to a small extent for the second crop in the Southern States.

Figs. 13, 14, 15, courtesy Cornell Univ. Dept. of Horticulture.

FIG. 13—POTATOES SPROUTED PROPER LENGTH FOR THE PLANTER
Starting the growth of the tubers in this way is profitable in many places.

FIG. 14—EARLY POTATOES SPROUTED FOR HAND PLANTING
Longer sprouts than these should not be permitted to deve lop.

By sprouting the seed tubers, the Kansas Experiment Station[1] have planted potatoes in March and lifted the crop on June 1. At the Rhode Island Experiment Station[2] potatoes were held in a fairly well-lighted room at a temperature of 60° to 75° F. for four to six weeks.

FIG. 15—SPROUTS TOO LONG AND WEAK

This often occurs when potatoes are left in sacks, barrels, or in piles in the cellar. As soon as sprouting begins, spread the tubers thinly on the barn floor, in the light, to check this waste of energy.

In this time thick buds, one-half to an inch long and one-quarter to three-eighths of an inch in diameter, formed (Fig. 14). The potatoes may be held at this stage for some weeks if necessary by lowering the temperature. Early Rose potatoes weighing about three ounces each were sprouted as described, and planted on May 1 beside similar tubers which were unsprouted.

[1] Kan. Bul. 70, p. 149, and Press Bul., March 6, 1899.
[2] R. I. Bul. 36, pp. 9-19.

Part of the crop was harvested July 29, the yield being decidedly in favor of the sprouted seed, which lead was maintained (see Table).

TABLE IV

YIELD PER ACRE FROM SEED TUBERS SPROUTED AND NOT SPROUTED

	Date Harvested	YIELD PER ACRE		Total	Gain by Sprouting	Increase from Further Growth
		Large Tubers	Small Tubers			
		Bushels	Bushels	Bushels	Bushels	Bushels
Sprouted.....	July 29...	97.96	53.23	151.19	32.31	.....
Not sprouted..	July 29...	76.10	42.78	118.88	.....	.....
Sprouted.....	Aug. 20..	135.47	55.51	190.98	54.63	33.79
Not sprouted..	Aug. 20..	94.45	41.90	136.35	.....	17.47

In trials made at Cornell Station by the writer during 1904, with the varieties Sir Walter Raleigh and Carman No. 3, increased yields of from 0.9 per cent. to 73.7 per cent. resulted from sprouting potatoes in the light for 36 days previous to planting, when compared with holding them in a root-cellar to the time of planting. The sprouts on the tubers held in the cellar were up to three inches long; those held in the light were but one-half to three-quarters of an inch long. No misses occurred, except from those sets held in the cellar. It seems probable that each variety may have its own optimum temperature, as conditions were uniform for both varieties. Eighteen hills were used in a plat, and Table V., on page 59, shows the results.

Another great advantage in sprouting is that it gives an opportunity to note variation and "rogue" the variety. Almost every variety shows a difference in the sprout, either in color or habit of growth; one

may have a white, spindly stem, which becomes green on exposure; another a short, sturdy stem, which becomes bright red; while another may be purple, and so on. So far I have found the "sprouting stage" the most reliable one at which to note differences in varieties, and varieties of potatoes may be distinguished as readily as varieties of other crops.

TABLE V

		SIR WALTER RALEIGH				CARMAN NO. 3			
			YIELD				YIELD		
No. of Plat	*Method and Temperature of Germination*	*No. of Misses out of Eighteen Sets*	*No. of Tubers*	*Weight of Tubers*	*Percentage Increase in Yield*	*No. of Misses out of Eighteen Sets*	*No. of Tubers*	*Weight of Tubers*	*Percentage Increase in Yield*
				Lbs.				*Lbs.*	
1	Cellar 50–60° F...	2	118	17.50	.....	0	93	15.25	.....
2	Cold Frame bottom heat 80° F. sash off.....	0	130	17.00	0.9	0	125	26.5	73.5
3	Cellar 50–60° F...	0	119	16.20	.....	0	89	15.25	.....
4	Barn, near open window 45–75° F.....	0	100	20.12	19.4	0	122	21.25	36.9
5	Cellar 50–60° F...	0	140	17.50	.....	0	107	16.25	.....
6	Greenhouse 78–90° F.....	0	127	20.25	22.0	0	85	16.25	4.1
7	Cellar 50–60° F...	0	94	15.75	.....	1	117	15.00	.....

The disadvantage of the system of sprouting potatoes is that the tubers must be planted by hand on account of the liability of knocking the sprouts off if passed through the planter. There are many local markets in the United States poorly supplied with early potatoes, and to supply such a small area of the crop could be profitably handled as above described. A distinction must be noted between the above method

and the slovenly practice of many who allow their seed tubers to send out long sprouts before planting, which are either broken off intentionally before or unintentionally during planting. This practice cannot be too strongly condemned.

The Trays may be made small to hold 40 pounds of potatoes, with a handle running lengthwise across the top, or to contain 80 to 100 pounds, and handled by two men, when the handles run across. The lumber for the trays, ready sawn in lengths, should be purchased at from five cents to ten cents per tray, according to size.

Whole Sets *vs.* **Cut Sets.**—Considerable attention has been given to the advisability of cutting seed tubers. The question is wholly a financial one, as in an average year with an ordinary late variety the weight of the seed planted is of more importance than whether it is whole or cut. Early varieties do not do so well when cut, and varieties with white flowers seem to be softer in texture and more liable to failure, if cut, than those with purple or colored blossoms. Some varieties cannot be cut with profit, owing to lack of bud-producing eyes.

The labor of cutting is often greater than the cost of the extra seed. When seed is expensive, as when a variety is new, it is wise to cut as far as possible to secure the largest possible yield in the least time, but this course must be followed by selection, or rapid deterioration of the variety will result. A potato cut into single-eye pieces, and each piece planted in a hill, will give a greater yield than it would had it been planted whole.

Time to Cut.—Formerly it was advised to cut the potatoes a few days before planting. Generally speaking, this is a mistake. Zavitz[1] reports as the result of hundreds of trials, during a period of eight years, that potatoes cut the day of planting gave 8 bushels per acre heavier yield than those cut four to six days before planting. Similar results were obtained at the Montana Experiment Station.[2]

Size of Seed.—It is a matter of general observation, supported by experiments, that large seed usually insures a larger yield than small seed. This may be due to the greater amount of nourishment furnished to the young plants, which enables them to make stronger growth, and to the greater hereditary vigor possessed by such tubers. Good-sized seed is especially desirable on light soils, and for early maturing varieties. Smaller seed from vigorous plants may be as satisfactory with late varieties, owing to their longer period of growth. The advisability of using large or small seed, cut or whole, depends largely upon the cost of the seed, the season, the culture given, and the price realized when harvested. Generally speaking, tubers weighing two to three ounces make the most profitable seed, as they are worth less for consumption. The amount of experimental work which has been undertaken to decide the influence of the size of the seed tuber upon the yield is enormous, and only a few references can be given here.

Fischer,[3] of Germany, advises (1) that under ordi-

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[1] Ont. Agr. College and Farm Report, 1898, p. 158; 1902, p. 127.
[2] Mon. Bul. 9, p. 21.
[3] E. S. R., IX., p. 331; X., pp. 361–367.

nary conditions large seed should be used, (2) on good soils with heavy fertilizing small tubers and closer planting is advisable; but that the small tubers shall be the progeny of large tubers grown on well-cultivated and fertilized soil, to prevent degeneration. Tubers which are small because the parent plant had not sufficient vigor to produce any larger are worthless for seed.

At Arkansas Station[1] whole tubers 2 inches to 3 inches in diameter yielded 18 per cent. more than small whole tubers ¾ inches to 1¼ inches in diameter, and large cut tubers 15.8 per cent. more than small cut tubers. At the Ontario Agricultural College[2] the largest yields for four years in succession were from planting large seed. Sets weighing one-sixteenth of an ounce and having one eye yielded, on an average, for the four years, 44.2 bushels, while two-ounce sets having one eye averaged 177.4 bushels per acre, and intervening sizes of sets yielded in proportion to their size. As the result of eight years' careful experiments, this station advises that large tubers be cut into pieces weighing about two ounces each for sets.[3]

J. C. Arthur,[4] of Indiana, conducted an elaborate set of experiments for three years to ascertain the relation of the number of eyes on the seed tuber to the product. He found that within certain limits the yield will increase with an increase in the weight of the set, and that the exact number of eyes per cutting is relatively unimportant. With tubers of the same weight and variety the number of shoots does not perceptibly

[1] Ark. Bul. 50, p. 28.
[2] Ont. Agr. Col. Report, 1898, p. 156.
[3] Ont. Agr. Col. Report, 1902, p. 126.
[4] Ind. Bul. 42.

increase with the increase of eyes on the tuber. Seed tubers weighing 1½ ounces and carrying 8 to 10 eyes sent up, on an average, 5.5 stalks per tuber, while seed tubers weighing 3 ounces and having 14 to 18 eyes sent up, on an average, 11.3 stalks per tuber. Bisecting an eye tends to increase the number of stalks, because each eye is usually a collection of buds, and some would be left uninjured on each piece. The number of stalks sent up tended to increase with the size of the seed tuber, and the yield increased with the increase in number of stalks.

The Virginia Experiment Station[1] reports that large seed cannot be used at a profit, while small seed is not recommended, but that sound tubers of the size of a hen's egg and upward are proper seed.

Green,[2] of Ohio, found that crops from whole seed mature a few days earlier than from the same sized seed cut in two, and that small cuttings require the soil to be in better condition than large cuttings, or whole potatoes, in order to secure a good stand and a profitable crop.

Amount of Seed Per Acre—Cost and Influence on Yield.—Plumb,[3] of Tennessee Experiment Station, found the largest seed tubers to be most productive and the least profitable, while those varying in weight from one to three ounces were most profitable.

At Kentucky Experiment Station[4] the amounts planted varied from six bushels per acre when medium-sized seed were cut to two eyes to 48 bushels per acre where large whole potatoes were planted. At the

[1] Va. Bul. 8, p. 3.
[2] Ohio Second Series Bul., Vol. III., I., p. 14.
[3] Tenn. Bul., Vol. III., I., p. 6.
[4] Ky. Bul. 22, p. 136.

TABLE VI

Amount of seed per acre. Bushels	Weight of seed tubers. Ounces	Distance planted apart. Feet	YIELD PER ACRE		Cost of seed per acre at 75c. per Bushel	Value of crop per acre at 40c. per Bushel	Balance after paying for Seed
			Bushels	Number of Tubers			
64	12–14	3	146	90,980	48.00	58.40	10.40
81	10–12	2	220	135,075	60.75	88.00	17.25
66	8–10	2	195	118,102	49.50	78.00	28.50
52	6– 8	2	168	115,273	39.00	67.20	28.20
37	4– 6	2	158	108,908	27.75	63.20	35.45
26	3– 4	2	146	104,665	19.50	58.40	38.90
18	2– 3	2	141	81,328	13.50	56.40	42.90
11	1– 2	2	128	67,184	8.25	51.20	42.95

Michigan Experiment Station[1] three varieties were tested, with results as shown in the following table:

TABLE VII

SIZE OF SEED	Amount of seed per acre		Yield per acre	Net yield in excess of seed	Net gain from using halves
	Bushels	Lbs.	Bushels	Bushels	Bushels
Halves	20	19	317	297	. . . . .
Quarters	9	54	254	244	53
Eighths	5	44	221	215	82
Single eyes . . .	4	10	178	174	133
Whole tubers . .	41	40	293	251	46

The writer has found from seventeen to twenty bushels to be necessary to furnish a good seeding, and others have advocated the same amount,[1] although a less quantity is frequently mentioned as satisfactory.

A compilation[2] of experiments made at thirteen stations to determine the proper amounts of seed shows:

1. Within ordinary limits, an increase in seed produces a marked increase in total yield and marketable potatoes.

[1] Mich. Bul. 57, p. 18.

[2] Mich. Bul. 93, pp. 5, 6.

2. An increase in the size of the seed from one eye to half a potato produces an increase in the net value of the crop.

A comparison of the half potato with the two eyes shows that:

1. For the total yield (large and small) of 95 experiments, 76 are in favor of the half potato and 19 in favor of two eyes.

2. For marketable yield (total less small) of 73 experiments, 58 are in favor of the half potato and 15 in favor of the two eyes.

3. For net marketable yield (marketable less amount of seed) of 30 experiments, 23 are in favor of the half potato and 7 in favor of the two eyes.

4. For net value of crop (value of crop less value of seed) of 30 experiments, 22 are in favor of the half potato and 8 in favor of two eyes.

A comparison of the whole potato with the half potato shows that:

1. For the total yield (large and small) of 54 experiments, 46 were in favor of the whole potato and 8 in favor of the half potato.

2. For the marketable yield (total less small) of 42 experiments, 36 were in favor of the whole potato and 6 in favor of the half potato.

3. For the net marketable yield (marketable less amount of seed) of 13 experiments, 7 are in favor of the whole potato and 6 in favor of the half potato.

4. For the net value of crop (value of marketable less value of seed planted) of 12 experiments, 7 are in favor of the whole potato and 5 in favor of the half potato.

The Value of Bud and Stem Ends and the Middle of the Tuber for Seed.—Many ideas have prevailed as to the relative values of different parts of the tuber for seed. Some growers advocate the removal of one end or the other, but thus far the experiments conducted at a dozen stations, including such varying points as Illinois,[1] New Jersey,[2] and North Dakota[3] Experiment Stations, show that there is no material difference noticable in yield that could be attributed to the different pieces, and that the two ends of a tuber are practically of equal value.

Viability.—The buds of tubers vary considerably in their ability to grow, and the same is true of the tubers themselves. Goff, of Wisconsin,[4] when using the variety Burbank, obtained a stand varying from 88 to 100 per cent. of the potatoes planted. The importance of proper moisture content of the soil is shown by the results reported in the following table by Woods, of Maine:[5]

TABLE VIII

VARIETY	STAND *Percentage of Cuttings that Produced Plants*
Rose	22
Early Michigan	46
Hulett's Rust Proof	37
Mill's Mortgage Lifter	20
Green Mountain	61
New Queen	1
Polaris	55
Maggie Murphy	50
Irish Cobbler	65
Early Ohio	57
Gem of Aroostock	28
Bovee	55

[1] Ill. Bul. 40, p. 132. [2] N. J. Report, 1898, p. 308. [3] N. D. Report, 1901, pp. 40–42. [4] Wis. Report, 1897, p. 306. [5] Me. Bul. 98, p. 183.

This poor stand was largely due to a very dry spell in May and June, and the differences observed in the various varieties may be due to the vitality of the varieties themselves, or to the way in which they were grown and stored, or to both causes. Girard, of France, summarized his experiments some time ago, showing the influence of the size of the tuber upon the "stand" and yield.

TABLE IX

WEIGHT OF SEED	*Percentage Number of Failures*	*Percentage Weight of Crop*
1—Tubers 3.5 oz. each, planted whole	6.0	100.00
2—Tubers 3.5 oz. each, cut into two portions	12.0	69.36
3—Tubers 7.0 oz. each, cut into two portions .	10.5	82.00
4—Tubers 10.5 oz. each, cut into three portions	14.5	74.00
5—Tubers 1.75 oz. each, two tubers planted together	3.7	95.36
6—Tubers 1.0 oz. each, three tubers planted together	3.7	89.12

The yield of No. 2 is not comparable with the others, because the same weight of seed was not used. Plats 1 and 3 are probably the best to use for ordinary consideration, and would show that from 90 to 95 per cent. of the tubers planted should grow, but it is a well-known observation that under adverse conditions —as, a dry season, ill-fitted land, etc.—a small cutting is not so likely to grow as a whole tuber.

The diagram (Fig. 16) shows that with Carman No. 3, where twenty plats were noted, there were 3 chances in 20 that the germination of the tubers and stand would be 100 per cent., and that it is much more likely to be between 91 and 98 per cent. than any other

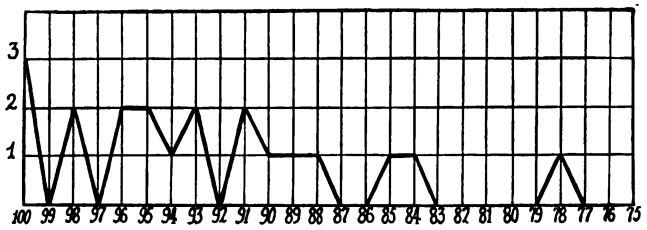

FIG. 16—DIAGRAM SHOWING STAND OF TWENTY PLATS OF CARMAN NO. 3 POTATOES[1]

The percentage stand is shown on the base-line. The hight of the curve from the base-line shows the actual number of plats.

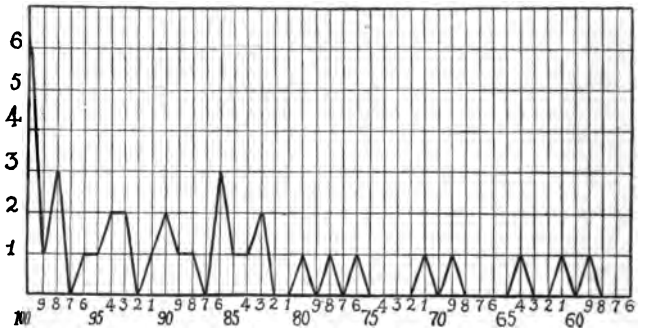

FIG. 17—DIAGRAM SHOWING STAND OF THIRTY-SIX PLATS OF EARLY TRUMBULL POTATOES[1]

The percentage stand is shown on the base-line. The hight of the curve from the base-line shows the actual number of plats.

number, although the average as usually worked out would show 93.5 per cent.

With Early Trumbull, using seed showing the rosette disease (*Rhizoctonia solani*) and some not showing it, treated with various fungicides, the average germina-

[1] From data in Ohio Bul. 145, p. 21.

ting power for 36 plats is 73.8 per cent. Yet, here again this does not convey a true impression, as on six plats all of the tubers germinated, and the table shows that there is a greater chance of securing a stand of between 83 and 98 per cent. than lower.[1]

The viability of tubers is injured or ruined if they heat or sweat to any extent; hence, if they have been treated with a solution, as for scab, it is essential that they be planted at once or spread thinly to dry. Potatoes may be ruined for seed purposes, if frozen, or if shipped in bags or barrels which have contained substances injurious to the buds—as, sugar, nitrate of soda, etc.; and even moving them on the farm in unwashed sugar-bags has been found to be dangerous. Immersion in water for more than a day may destroy the buds, and probably cause the tuber to decay in a few days. By this means potatoes have been destroyed in pits and in the field when floods have occurred. Soaking them in too strong a solution of formalin or other preservative is liable to reduce viability, because the formalin tends to preserve the tuber and prevent its decomposition.

Potatoes which have been subject to diseases may be weakened and their vitality impaired.

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[1] From data in Ohio Exp. Sta. Bul. 145, p. 21.

CHAPTER VII

VARIETIES

Selecting a Variety.—For general farming it is advisable to grow only a few varieties. Most successful growers seldom have half a dozen growing for marketing, and usually one is selected as more suitable than the rest. The beginner is advised to select a variety from the more thoroughly tested kinds that have done well in his immediate vicinity and on his type of soil. The seed should be obtained from a reliable grower or a responsible seedsman. The importance of growing the best varieties cannot be too strongly emphasized. To many a potato is a potato, and anything is used for seed. Such haphazard methods cannot survive. Potatoes are grown for human consumption, and the public taste must be considered. Good quality and good yield are required. In some localities good quality potatoes appear to be grown in spite of adverse conditions, but not all of the crop can be produced in this way.

Some of the points to consider in selecting the variety are:

1. *Good cooking quality and flavor.* This is partly influenced by the soil, season, ability to mature before frost, etc.
2. *The yield.* The late maturing varieties usually yield heavier than the early varieties. Yield is influenced, among other things, by the adaptability of the variety to the district and soil.

3. *Ability to resist diseases.* The potato is so subject to disease that this is now of prime importance in a variety in the Eastern States, although not so important in parts of the Trans-Mississippi area.
4. *The color of the skin and tuber.* In the Eastern States red varieties are not in favor at present, a white-fleshed and white-skinned tuber being preferred. In the South red-skinned varieties are sought.[1]
5. *The nature of the skin.* A netted, or rough, skin is preferred.
6. *The shape.* Some markets discriminate in favor of a particular shape, the flat-round and oval generally being popular shapes.
7. *The depth and frequency of eyes.* Potatoes with deep and numerous eyes are not economical in preparation for cooking.
8. *The time of maturity.* This is essential to know before planting, in order to facilitate the distribution of farm work and determine whether it is likely to mature in the locality.
9. *The haulm.*
10. *The leaf.*
11. *The vigor of the variety.* This is important, although it is of equal importance to obtain a vigorous strain of a variety, as wide variations are noted in the same variety.
12. *Tendency to make second growth.*

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[1] Tex. Bul. 71, p. 9.

13. *Trueness to type.* It is essential that the seed be as represented. As none but an expert can tell the different varieties apart, seed should be obtained from a reliable grower or a responsible seedsman.

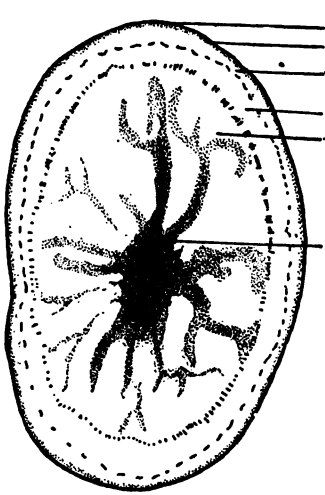

FIG. 18—SECTION OF A POTATO OF POOR COOKING QUALITY

P—Envelope, or Periderm, consisting of an inner and outer layer. *P.L*—Pigment layer, where coloring-matter of the skin is found. *E.C*—External Cortical, or Cambium layer, usually poor in starch. *I.C*—Internal Cortical, or Cambium layer, rich in starch. *E.M*—External Medullary layer, rich in starch. *I.M*—Internal Medullary layer, or pith, or water-core, poor in starch.

The objectionable features of this tuber are large pith area and lack of uniformity in cellular structure. Each layer is readily recognized, and each one varies in the amount of time required for cooking; hence, it is of poor cooking quality. (Compare with Fig. 19.)

1. *Cooking quality and flavor* are two of the factors which determine culinary value. They are distinct. Cooking quality is recognized in a boiled potato by mealiness or sogginess. This appears to depend upon the physiological structure of the tuber, and is not necessarily connected with chemical composition (Figs. 18, 19). A potato showing uniformity in the distribution of starch in the various layers may be considered to be of better quality than one not showing this uniformity. Immature potatoes tend to be soggy

when cooked. Mealiness is due to the union of the starch grains in a cell into one mass, and the rupture of the cell walls during cooking. Sogginess occurs when the cell walls retain their form. Opinions differ as to what constitutes good cooking quality. Americans like a white, mealy, or floury, potato. The French prefer a yellow, soggy potato which retains its shape when boiled.

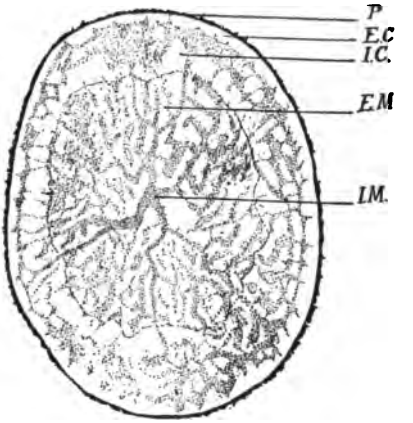

FIG. 19—SECTION OF A POTATO OF GOOD COOKING QUALITY

(Compare with Fig. 18.)

The desirable features of this tuber are well-netted skin, showing maturity; large Internal Cortical (*I.C.*) and External Medullary (*E.M.*) layers, which are rich in starch; small pith area (*I.M.*), with marked uniformity in cellular structure. The different layers nearly approach each other in appearance, and cook uniformly.

Good cooking quality can be determined by cooking. The common method is to take a sample and steam or boil some of the potatoes. When cooked the potato should be dry and floury, free from wetness, and readily break to pieces on slight pressure, or be readily reduced to a coarse meal free from hard lumps. The particles should glisten as though crystalline, and the potato should have a white color, which is retained when cold. Potatoes which

are yellow when cooked, or turn dark or black, are not considered of good quality, even if the flavor is good, and can be sold only to a low-class trade. Tubers must not be hollow in the center, as this gives rise to a hard, dark-colored core, which is decidedly objectionable if potatoes are to be mashed.

Some varieties will cook better if they have been kept; they are, in other words, for spring use. Thus, in New York, Carman No. 3, White Star, and Doe's Pride come in this category.

The flavor should be mild, and free from earthiness.

2. *The yield.* The average yield of potatoes from one plant in the United States is about half a pound. Having weighed the yield of hundreds of potato plants during the past year, we find that in the case of Early Ohio one plant yielded three tubers weighing half an ounce, while another yielded thirteen tubers weighing two and a half pounds. The latter yield is eighty times the former. In late varieties plants yielding four pounds of tubers were found. In some of the recent English productions whole plats would average six pounds of tubers per plant, while individual plants have yielded over twenty pounds of potatoes, as many as 150 potatoes being set on one plant.[1] These facts emphasize the value of the farmer selecting seed himself and eliminating the poor plants. All the tubers from the best plants should be saved and planted separately to produce the seed for the following year. The expenses of growing a poor and a heavy crop vary little. The only additional cost of the latter is

[1] *Gardener's Chronicle*, Oct. 15, 1904, pp. 276–278.

a little more for digging. The variety controls the yield to a large extent, and there is much more likelihood of obtaining a 300-bushel crop from a variety capable of yielding 600 than from one whose maximum yield is 300 bushels. This fact is realized, and the high prices paid in recent years in Great Britain for seed potatoes of good quality, heavy yielding, and disease-resisting varieties are legitimate and proper recompense to the men who have the skill to breed such. These new varieties are profitable to grow because there is an assurance that the crop will yield well, and that it will keep well; hence there is an opportunity to hold it until it can be sold at a profit. These farmers realize that the best is none too good, and that it is useless handling varieties that are out of date. The potato grower of Great Britain and Europe must be up to date if he is to stay in the business. High-priced seed receives more care in storage and is handled more intelligently, the seed-bed is better prepared, and the result is better farming. The farmer who grows such crops is a more thoughtful and better business man, as slovenly methods have to be abandoned.

Yield is influenced by the size and number of tubers at a root. Uniformity and good size are desired. Potatoes vary in size from almost nil to six pounds each or more. In Doe's Pride one plant set 21 tubers, varying in size between 1-10 ounce and 6½ ounces; in other words, one potato was 65 times larger than the other. In the East potatoes over 8 ounces in weight are large. Medium-sized tubers of merchantable value vary between four and eight ounces. Sec-

onds between two and four ounces, and tubers less than this weight, are hardly worth picking up.

3. *Ability to resist diseases.* No varieties can be termed "disease proof," but many varieties are better disease-resisters than others. Stuart, of New Hampshire, found that the variety Hulett's Rust Proof was the only one that was disease-resistant out of several varieties, although the varieties Dakota Red, Green Mountain, New Queen, and Enormous showed some resistance. Hulett's Rust Proof falls below the requirements in other respects and is of little value, and in Minnesota has been found to be subject to disease. At Ontario Agricultural College, Carman No. 3 and Stray Beauty resisted disease well. At Minnesota Experiment Station, Rural New Yorker and Sir Walter Raleigh showed some resistance.[2]

4. *The color of the skin and tuber.* Many of the colored-skinned varieties of potatoes, and those showing a blush of pink—as, the Beauty of Hebron, Early Rose, etc.—belong to a type which have white blooms. They are generally early maturing, rather liable to disease, and of good quality, according to the American standard. The colored-skinned early varieties are generally more readily sold than the late ones, although in some districts colored-skinned potatoes are not objected to on the market. All colored-skinned potatoes are not deficient in vigor. Some are among the best disease-resisting and best-flavored varieties, but the red color of some weak varieties has rendered some growers skeptical of all.

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[1] Minn. Bul. 87, p. 2.

[2] Minn. Bul. 87, p. 10.

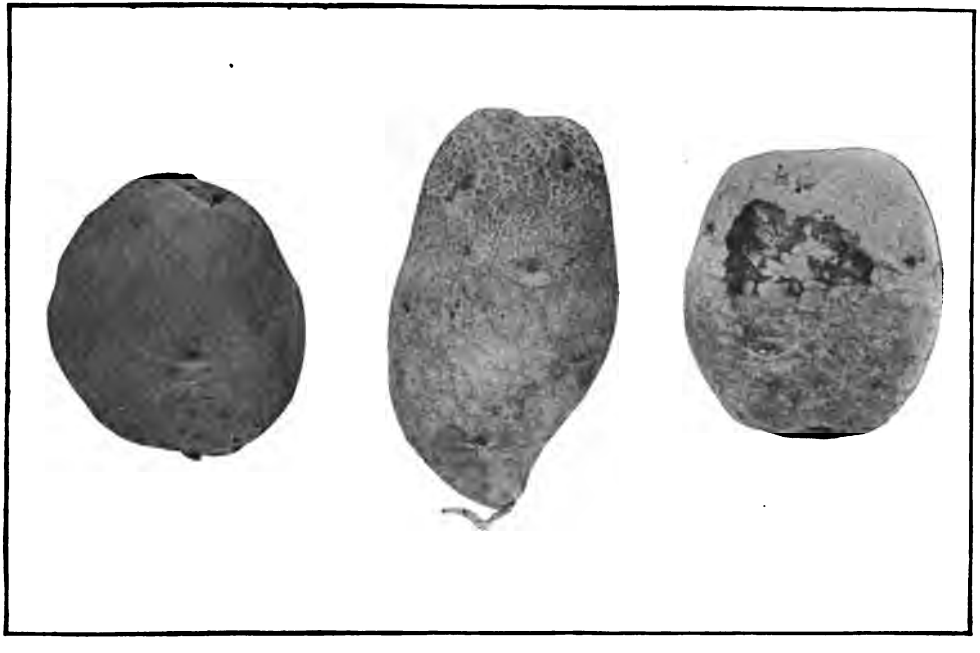

FIG. 20—THREE VARIETIES DIFFERING IN CHARACTER OF NETTING OF THE SKIN
A well-netted skin usually indicates maturity.

5. *The nature of the skin.* The skin may be thick, medium, or thin. Some growers claim that thick-skinned varieties are of better quality than thin-skinned ones, but such correlation does not always exist. Potatoes grown on sandy soils usually have smoother skins than those grown on heavy loams. Some varieties develop a netted, or rough, skin as they mature in storage, although such may not be apparent at harvest-time. The rough, or netted, skin in these cases appears to denote maturity, and this may account for the common idea that a rough-skinned potato is of good quality. The size and type of netting (Fig. 20) varies with the variety, and the conditions under which it is grown.

6. *The shape.* Most of the recent introductions, exclusive of the Early Rose type, have had a tendency to partake of the flat-round or oval (Fig. 21). These shapes have been sought because such potatoes appear to be of better quality consistent with an economical shape and shallow eyes. The probable explanation is that in a flat-round or thinnish potato there is a greater surface in proportion to the bulk. The greater the surface the larger the percentage of the tuber taken up in the cortical layer and outer medullary layer (Fig. 18). These are the starch-bearing areas, and as they are increased the inner medullary layer, or pith, which has little starch, is diminished, thus rendering the potato more uniform. Whatever shape is desired can be be obtained, but a potato should be true to shape. The tendency of a tuber to become pointed or drawn out at the tip or butt end, especially if the variety is a flat-round or round, indicates lack of vigor (Fig. 21).

7. *Depth and frequency of eyes.* Deep eyes (Fig. 21), to some extent, are regarded as associated with robust-

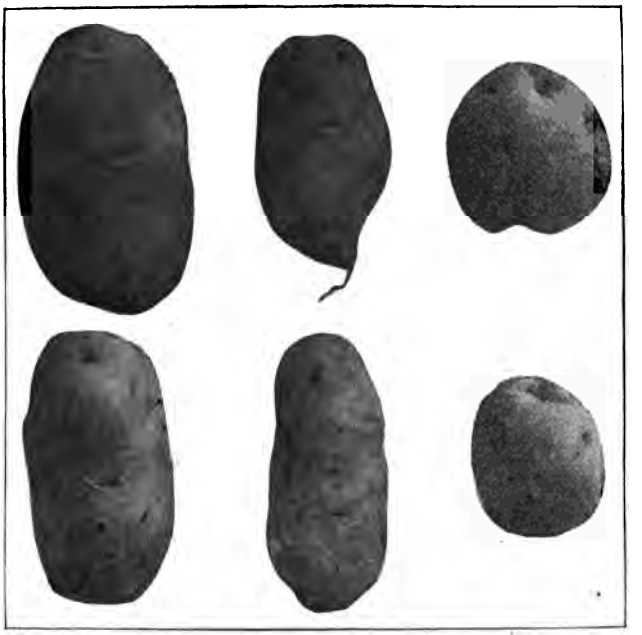

FIG. 21—THREE FAVORITE SHAPES OF POTATOES
(*Upper row*, the broad surface; *lower row*, the narrow surface.)
Beginning on the right, the small one is a flat-round; the center one, kidney; the largest one, on the left, elongated oval. Notice the shallow, wide eyes on the latter; they are the most desirable. The eyes of the flat-round are too deep.

ness and, frequently, coarseness. They are wasteful in peeling. Deep eyes tend to hold moisture, which hastens decay when the potatoes are stored.

8. *Time of maturity.* In the Northern States pota-

toes are classified into early, medium or second early, and late varieties, according to the time they take to reach maturity. Early varieties may mature in 70 to

FIG. 22—THE IMPORTANCE OF HAVING UPRIGHT HAULM AND PRESERVING THE FOLIAGE IS NOT SUFFICIENTLY APPRECIATED

Plant photographed early in September, 1904, when many others near were dead (C. U. Farm). Upright haulm facilitates late cultivation and spraying. The foliage dries quickly, and then is not so favorable for the growth of spores of rot.

90 days after planting; second earlies, in 90 to 130 days, while late varieties may continue to grow for 200 days.

9. *The haulm.* The haulm and leaf are receiving more attention to-day than formerly. The size of haulm has an influence upon the distance apart of planting. Large haulm is more trouble to spray, re-

quiring more solution, and it is always lying over the ground when the last spraying ought to be given, and is in the way at lifting-time, whether the potatoes are raised by hand or digger. Modern breeders aim to produce a short haulmed, upright, heavily leaved top, because the upright habit of growth (Fig. 22) is more likely to keep clear of disease than a spreading habit, owing to water being shed from the former more readily than from the latter, and not offering a foothold to the disease spores (Fig. 37). Plants whose branches lie on the ground are more liable to disease because they cover a greater area, their leaves, touching the ground, are almost always damp from contact with it, and sun and wind cannot so readily reach them. Very tall haulmed varieties are readily beaten down by storm and wind, and in this state they cannot dry so readily; hence, they fall in a clammy mass, very favorable for the growth of disease spores.

Varieties with strong, hardy haulm suffer less from spring frosts. Late varieties usually have taller haulm than first early varieties. Some varieties make their heaviest growth of foliage late in the season, and in this way are not so subject to attacks of early blight.

10. *The leaf.* The British disease-resisting varieties have hard, thick leaves. Whether the thickness of the leaf is an important factor in their resistance to rot (*Phytophthora infestans*) is not determined. The fact that spraying the upper surface of the leaf tends to prevent blight would seem to show that access to the inside of the leaf is obtained by growth through the cell walls as well as through the stomata, on its under surface. If this be true, then the thickening and hardening

of the cuticle and the palisade cells (Fig. 34), or thick cells on the upper surface of the leaf, will no doubt prevent many spores from reaching the inside cells of the leaf. They may germinate on the surface, but not enter, unless they find some place where the leaf has been injured. The punctures of the flea-beetles are, on this account, of great importance, as they furnish an entrance to the inner cells (Fig. 40).

N. A. Cobb, of Australia, has shown that in the case of wheat the varieties most resistant to rust (*Puccinia graminis* and *P. rubigo vera*), none being absolutely resistant, have narrow, stiff, upright foliage, while those most liable to attacks have broad, flabby, and pendant foliage. In the plants resistant to rust the cuticle of the leaf is much thicker than in the others, and is so thick that the rust spores, when they germinate on the outside of the leaf, cannot penetrate it, or if they do succeed in entering the leaf through stomata, the threadlike growths of the parasite cannot rupture the cuticle wall to fructify ; and, further, some wheats have stomata so narrow and are so well covered with wax that the germinating threads of the rust spore fail to enter every time. These circumstances seem to support the claim that the tough, thick-walled, hard, dry leaf is the one to select for disease-resistant powers. It has been observed that plants of the potato family having this type of leaf are fairly free from fungus leaf diseases. It is essential that the leaves of the potato be abundant to insure a good yield.

11. *The vigor of the variety.* Vigor is the power stored in a plant which enables it to overcome difficulties at different periods of growth. A variety must

have vigor. If not, it may fail to establish itself during the early part of its career, being a shy budder; it may be readily injured by frost, heat or cold, drouth or a wet period, and, having little recuperative power, will give small returns for the labor bestowed upon it. If it survives to tuber-formation time it will probably fail then. Plants or varieties showing lack of vigor must be discarded. Some varieties have short staying power; they appear to be vigorous for one or two years, and then suddenly collapse. Others have great staying power—as, Early Rose, which has been prominent for over forty years.

The statement is sometimes made that modern varieties are not so long-lived as their ancestors—that they are deficient in staying power. If the statement were true, it might be explained by saying that new varieties are produced more frequently, and that on account of their heavier yielding power or better quality they displace the old ones. The facts seem to show that modern potato breeders have more than maintained vigor and staying power. Hays, of Minnesota, and others, place the life of a good modern variety at about thirty years. This seems to be accepted by many, both here and abroad. Dr. Hunter, of England, in his "Geological Essays," [1] writing about one hundred years ago, states "that varieties continue in vigor about fourteen years, after which the produce gradually declines." Shirreff and T. A. Knight held similar views; the latter wrote [2] that "not a single healthy

[1] "Geological Essays," Exp. 14, p. 348.

[2] Hort. Trans., Vol. I., and Miller's "Gardeners' Dictionary," ed. 1807, "Potatoes."

plant of any sort of potato that yields berries, and which was in culture twenty years ago, can now be produced." So late as 1838 this idea was accepted by the horticulturists of England.[1] It is interesting to note that the average yield of potatoes in England a hundred years ago is stated to vary between 185 and 300 bushels, and sometimes 440 bushels, per acre. The average yield to-day is about 230 bushels, but some growers produce 750 bushels per acre frequently. The average improvement in the quality of the tubers is greater than the average improvement in yield. Formerly the potatoes were grown largely for stock, and were of poor flavor and bad cooking quality.

Some new varieties make vigorous growth, and, becoming bark-bound, the skin cracks. Such varieties are regarded as of coarse and inferior quality, and lacking in appearance. This character may be eliminated by judicious selection. Deficiency in vigor is indicated by the formation of misshapen tubers drawn out at either end, the presence of second growth, weak buds, lack of uniformity in texture—as, hardness at the ends of the tubers when cut, especially brittleness of texture. Tubers showing any such characteristics should not be planted.

When potatoes are planted 15 inches apart in 36-inch rows, there are 11,616 plants per acre. If each plant had sufficient vigor to yield three tubers, each weighing half a pound, or four weighing six ounces each, a yield of 290 bushels of salable potatoes per acre is assured. No one can afford to use seed of less vigor than this.

[1] Don's "Gardeners' Dictionary," 1838, Vol. IV., pp. 400-406.

12. *Tendency to make second growth.* Second growth (Fig. 38) is most prevalent in a season when drouth is followed by a wet period. The drouth checks the development of the tubers, causing them to begin to mature, while the subsequent wet period restarts growth. If one variety or a plant does not show any such abnormal growth, it is regarded as being more vigorous; hence, other things being equal, such should be used for seed, and all showing second growth should be rejected. Abnormalities in shape may be due to contact with stones or hard lumps.

13. *Trueness to type.* This may be viewed as embracing several considerations. In new varieties there is always more or less tendency to lose the features for which the variety has been selected. The type is then said to be insufficiently fixed, and often those which depart from the type degenerate. In such cases selection must be continued.

Many varieties are deliberately or unintentionally sold for something else. Mixtures of varieties are sold as one. Good varieties are often renamed and sold by unscrupulous seedsman and others as something new. There is considerable duplication of varieties of potatoes;[1] thus, Brooks, of Massachusetts,[2] believes, after growing the following varieties, that King of the Earliest and Early Ohio, Salzer's Earliest and Bliss Triumph, Mills' Banner and Livingston Banner are identical, and that White Beauty and Cambridge Russet differ but slightly. Mills' Mortgage Lifter is often sold as Burpee's Extra Early. Some dealers

[1] Wyo. Bul. 32, p. 65. [2] Hatch (Mass.) Sta. Report, 1899, p. 81.

have been known to deliberately rename a well-known variety and sell it as their own, and as a new and heavy yielding variety.

Dakota Red is sold for Bliss Triumph, although inferior in quality. The above is not a complete list, but will show that this state of affairs exists, and emphasizes the importance of dealing with a firm who have a reputation to lose.

Testing Varieties.—It is advisable to secure copies of experiment-station literature and papers in which variety trials are reported. The best variety for one soil is not the best for another. The only way to have the best is to make a trial with small quantities of different varieties. Secure seven to ten pounds of seed of each new variety, and plant, say, three rows of each on a piece of land as uniform as obtainable, using a standard variety, called *A*, as a check. If we take *B*, *C*, *D*, *E* as four untried varieties, buy the seed in the fall, hold it all, including the *A* seed, under similar conditions, and plant under similar conditions in the following order: *A*, *B*, *C*, *A*, *D*, *E*, *A*. Treat all plats alike in every respect, dig when ripe, and weigh the crop. If the *A* plats yield approximately the same, then the deduction is that the soil conditions are fairly uniform. If not, compare the yield of each plat with the yield of the *A* plat nearest to it. Conduct the trial for three years. I find that the second and third years' results are better than the first, as the conditions are more uniform, although if a variety is a long way ahead the first year and shows up well in other ways, I would increase the area under it at once.

Relationship of Variety to Soil.—Disappointment and loss are often the result of not knowing and studying the environment best suited to a variety. Each variety, and probably each individual in a variety to a lesser degree, has its idiosyncrasies, and, to succeed, these must be recognized and catered to. The failures in potato-growing deserve more attention. The successes take care of themselves. The careful grower takes note of the failure and the success. Both have a cause or causes, and the climatology and character of the soil may be among them. Some varieties do better on a heavy loam than on a sandy loam, probably because the former is cooler, owing to its greater moisture content, and under such conditions these varieties give a higher return of starch per acre and are of better quality. Other varieties, as those inclined to be coarse and rough, do better on sandy loams. In this class are Eureka and Uncle Sam.

Some require a rich loam soil—as, Early Ohio, Bovee, Early Harvest, Early Michigan. T. L. Watson,[1] of Virginia, also noted that some varieties want more plant-food than others, other conditions being the same. Others are more cosmopolitan—as, Carman No. 3, Early Rose.

The Most Popular Varieties.—With the object of ascertaining the best variety as determined by yield in different places, a letter was addressed to the director of each experiment station and to some growers; 49 replies were received; 28 men mentioned varieties which had yielded or appeared to be best in their

[1] Va. Bul. 56, p. 144.

districts. In all 59 varieties were mentioned. Tabulating the data presented, we find that 21 of these varieties were mentioned twice or more. In the Southern and Southern Trans-Mississippi States all varieties mature about the same time and may be classed as earlies, and early maturing varieties are usually planted. Of these and the early varieties, as grown in the North, Bliss Triumph and Early Ohio are the most popular with ten votes each; Six Weeks Market received five; Early Rose, four; Burpee's Extra Early and Bovee, three each; while Beauty of Hebron, Early Fortune, Eureka, Irish Cobbler, Michigan, and Polaris had two each. Among late varieties, Green Mountain leads with eight votes, Carman No. 3 had five, Rural New Yorker and Sir Walter Raleigh had four each, and Burbank, Carman No. 1, Vermont Gold Coin, Rural New Yorker No. 2, and Freeman had two each. Although the above method of determination may not be absolutely correct, undoubtedly the varieties mentioned are among the favorites.

Station	*Leading Varieties*
1. ALABAMA, Tuskegee .	Early—Bliss Triumph. Medium—Early Rose. Late—Peerless.
2. ALABAMA, Auburn . .	Triumph.
3. ARIZONA	Burpee's Extra Early, Triumph, Early Rose.
4. ARKANSAS	Red Bliss, Ohio, Michigan, Six Weeks, Crown Jewel.
5. CALIFORNIA	Burbank.
6. CANADA, Ontario . .	Extra Early — Pinkeye, Stray Beauty, Early Ohio. Medium—Burpee's Extra Early, Rose of the North. Late—Empire State, American Wonder.

Station	*Leading Varieties*
7. COLORADO	Medium—Queen of the Valley, Rose Seedling. Late—Pearl, Rural No. 2.
8. CONNECTICUT	Late — Green Mountain, Carman No. 3, Rural New Yorker.
9. ILLINOIS	Early—Early Ohio.
10. IOWA	Vermont Gold Coin.
11. KANSAS	Early—Six Weeks. Medium—Early Ohio.
12. G. L. FOSS, Fort Fairfield, Me. . .	Early—Early Ohio. Medium—Burpee's Extra Early. Late—Green Mountain.
13. MARYLAND	Late—McCormick.
14. MASSACHUSETTS . . .	Beauty of Hebron, Early Rose, Early Andees, Early Dawn, Triumph, Salzer's Earliest, I.X.L., Steuben, Early Nancy, Million Dollar.
15. MONTANA	Early—Six Weeks Market, Early Ohio. Medium—White Ohio, Rural New Yorker. Late—Freeman, White Main.
16. NEBRASKA, Bul. 80 . .	Early—Early Ohio. Late—Rural New Yorker.
17. NEW HAMPSHIRE . .	Late—Green Mountain, Washington.
18. NEW YORK, Cornell . .	Early—Early Ohio, Bovee. Late—Green Mountain, Carman No. 3, Sir Walter Raleigh.
19. NEW YORK, Geneva .	Early—Michigan, Early Trumbull. Late—Carman No. 3, Uncle Sam, Whiton's White Mammoth, Sir Walter Raleigh.

Station	*Leading Varieties*
19*a*. Prof. STEWART, Geneva, N. Y. .	Rural New Yorker No. 2, Carman No. 3, Green Mountain, Sir Walter Raleigh. (Most popular late varieties in the State, apparently.)
20. LONG ISLAND, N. Y. .	Carman No. 1, Green Mountain.
21. NORTH CAROLINA . .	Bliss Triumph (both red and white skinned), Bovee, Eureka, Houlton Rose, selected strains of Early Rose. Late—Green Mountain, Washington.
22. OHIO	Early Ohio, Six Weeks. Medium—Bovee, Early Fortune.
23. OKLAHOMA	Bliss Triumph, Early Ohio.
24. PENNSYLVANIA . . .	Early—Extra Early Crusaders, Six Weeks, Irish Cobbler, Beauty of Hebron. Medium—J. A. Totten, Freeman.
25. RHODE ISLAND . . .	Early — Early Harvest, Early Fortune, Polaris. Late—New Queen.
26. TENNESSEE	Triumph.
27. TEXAS, Bul. 71 . . .	Triumph (generally grown), Thorburn, Irish Cobbler, Eureka.
28. M. ALEXANDER, Charlotte, Vt. .	Early—Triumph. Medium—Polaris, Garfield, Early Vermont, Charles Downing. Late—Green Mountain, Delaware, Alexander's Prolific, Dakota Red, Gold Coin, Sir Walter Raleigh, Carman No. 1, Carman No. 2.
29. WASHINGTON	Burbank.

CHAPTER VIII

PLANTING

Distance Apart.—As potato roots spread laterally to a distance of 2 to 2.5 feet, the potatoes might be planted in rows four to five feet apart without the roots overlapping in the feeding-ground. The advantage of such distances would be that intertillage could be maintained until quite late in the season, and that there would be opportunity to spray the plants as late as one wished. Whether such distances would be economical is a local question largely controlled by the supply of moisture available for the crop. In Colorado the potatoes are usually planted in rows four feet apart. In humid climates 30 to 36 inches is more common, and 27 inches and even less is profitable in some cases. Other factors are the value of land and the cost of labor. Where land is low in value and labor high, wider rows and the use of machinery are necessities. With high-priced land and low-priced labor the rows may be much closer together, and a much larger yield per acre may be possible.

The most suitable distance probably varies with each variety; it certainly varies with some. For spraying purposes a variety with long, straggling haulm requires more space than one with short, upright haulm. Most of the early varieties belong to the latter type, and such are planted closely. Rows 27 to 30 inches apart, with plants 8 to 12 inches asunder, for early varieties, and

30 to 33 inches, with plants 12 to 18 inches asunder, for late varieties, are suggested for most Eastern conditions. For irrigation experiments in Wisconsin, King[1] used 30 x 15 inches with success. In Europe, where heavy

FIG. 23—EARLY MATURING VARIETIES
These generally have dwarf haulm, and may be planted much closer together than the later ones. This plant grew about one foot tall.

yields are obtained, the potatoes are planted close together; thus, Vuyst,[2] of Belgium, and Lavalée[3] advise that the rows be 24 inches apart and the plants 12 inches asunder, because of the increased yield, the hastened maturity, and better-formed tubers. Westermeier,[4] of Germany, states that about 360 square inches for each plant gave the highest yield on a humous

[1] "Irrigation and Drainage." F. H. King.
[2] E. S. R., V., p. 232.
[3] E. S. R., XII., p. 1032.
[4] E. S. R., VII., p. 681.

loam. This would result from rows 30 inches apart with plants 12 inches asunder. In the United Kingdom my observation is that 27-inch rows with plants 12 to 15 inches asunder for late varieties and 8 to 12 inches for early (Fig. 23) and second early varieties is most popular. The Maryland Station[1] reports 25 per cent. heavier yield from planting 30 x 14½ inches than from 36 x 12 inches. The average of Canadian[2] experiments for the six years, 1896-1901, shows that 12 to 14 inches asunder in 30-inch rows was better than 10, 16, or 18 inches, whether considered from the standpoint of total yield or of total yield *minus* the seed. At North Dakota Experiment Station,[3] with 40-inch rows and the variety Early Ohio, it was better to plant the sets 10 inches asunder than at greater distances.

Depth of Planting.—The best depth varies to some extent with the soil, climate, and season. It is better to plant deeper on an open or light soil than on a compact or clay soil, in order to insure a more uniform temperature and moisture supply. These conditions aid in the production of good quality tubers. In a wet or a cold climate shallow planting may be good practice. In a wet season, on a compact soil, 1 inch or 2 inches deep seems to be best. The Michigan Experiment Station[4] reports that on a sandy loam, in 1892, the yields of potatoes planted at various depths were, per acre: 2 inches deep, 275 bushels; 3 inches, 298 bushels; 4 inches, 279 bushels; 5 inches, 273 bushels; 6 inches, 238 bushels. At North Dakota Ex-

[1] Md. Bul. 31, p. 77.
[2] Can. Exp. Farms Report, 1901, p. 117.
[3] N. D. Report, 1901, p. 96.
[4] Mich. Bul. 95, p. 9.

periment Station 3 to 5 inches deep gave the heaviest yields, but 5 to 6 inches deep is recommended, as tubers of better quality are produced.[1] While in a dry season, on a rich clay loam soil, Green[2], of Minnesota, obtained better results from deep planting, the yields being, per acre, planted on the surface, 216 bushels; 3 inches, 227 bushels; 6 inches, 297 bushels; 8 inches, 328 bushels, it was felt that the results would have been different if the season had been wet. The New Jersey Experiment Station[3] obtained similar results, but found a depth of 4 inches most profitable. From the data submitted and other sources, 3 inches to 4½ inches seems to be the most profitable depth.[4] On soils which are heavy and bake, and under certain climatic conditions, the seed should be planted fairly deep, but not covered more than 2 inches or so, to aid germination.[5] The soil can then be gradually worked toward the potatoes until level culture is obtained. This system is sometimes advocated for the second crop in the South.[6]

Influence of Depth of Planting on the Depth at Which Tubers Form.—This question is of importance, because mechanical diggers must be used, and it is essential to know the depth to which they must work in order to dig all the crop. Zavitz,[7] of Ontario, as the result of three years' trial, found that on an average potatoes from tubers planted

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[1] N. D. Report, 1901, p. 97. [2] Minn. Bul. 10, p. 74.
[3] N. J. Bul. 120, p. 10, and Botanist's Report, 1896, p. 318.
[4] Ga. Bul. 29, p. 304. Tex. Bul. 71, p. 7. [5] Pa. D. A. Report, 1902, p. 722.
[6] Ga. Bul. 29, p. 305. [7] Ont. Agr. Coll. Farms Report, 1894, p. 98.

One inch deep were formed 2.3 inches below the surface;
Three inches deep were formed 2.9 inches below the surface;
Five inches deep were formed 4.1 inches below the surface;
Seven inches deep were formed 6 inches below the surface.

It was observed that those planted 1 inch deep furnished many sunburned potatoes, while those planted deeper had almost none. Gilmore, of Cornell, obtained somewhat similar results during the year 1904.

Goff,[1] of Wisconsin, planted the Burbank variety at different depths, and found that shallow planting insured greater germination and more tubers per hill, but that they were nearer the surface and had more exposed tubers.

TABLE X

Depth of Planting	*Hills Germinating*	*Tubers Protruding from Soil*	*Average Number of Tubers per Hill*	*Average Weight of Tubers per Hill*	*Average Depth to Deepest Tuber*
	Per cent.	*Per cent.*		*Pounds*	*Inches*
2	100	8.4	6.6	.58	2.5
4	96	.8	5.4	.62	3.5
6	88	....	3.2	.35	5.0

The Canadian Experiment Farms[2] report, as the result of four years' trials, that with tubers planted 1 inch to 8 inches deep, where the sets were planted less than 4 inches deep, nearly all the tubers were formed between that depth and the surface, and when planted deeper than 4 inches most of them formed within 4 inches of the surface. The deduction made from these results was that the potatoes developed in the surface

[1] Wis. Report, 1897, p. 306. [2] Can. Exp. Farms Report, 1901, p. 117.

4 inches of soil because it was warmer than the 3 or 4 inches lower down.

Influence of Depth on Quality.—On a sandy loam, under New York conditions, potatoes grown about 4 inches deep are generally of better quality than those grown nearer the surface. In other places, those grown at even greater depths have been observed to be of better quality; thus, at North Dakota Station,[1] potatoes 5 to 6 inches deep were better than those 3 or 4 inches deep in this respect.

Date of Planting.—As would be expected, the dates of planting potatoes vary widely, and the only way to deal with the question is to give the common dates for a certain locality. The reader is advised to inquire of the growers in the locality the date considered best, and, as a general rule, it is wise to plant early for the district. Canadian experimenters[2] report, after four years' trial, that the end of May is the best time, and that June 24 is usually found to be the latest date for planting potatoes to produce satisfactory returns, although in 1900 a good crop was obtained from a planting on July 7. In Wisconsin the middle to the end of May, and in Maine late in May and early in June, are considered best. At Cornell University, in 1901, potatoes planted May 16 yielded 250 bushels per acre, while those planted June 12 and 17 yielded 162 and 197 bushels respectively. In Oklahoma[3] potatoes planted March 14 came up and matured as early as those planted February 27. The early potato crop of Virginia is usually planted during February and March,

[1] N. D. Report, 1901, p. 96.
[2] Can. Exp Farm Report, 1901, p. 119.
[3] Okla. Bul. 52, p. 9.

and the second crop about August 1. In latitude 33° the dates are about two weeks later.

Influence of Late and Early Planting.—The practice of growing a late crop of potatoes has spread northward, and in parts of New York it is customary to plant potatoes late in the season after another crop, as peas, has been removed. The practice seems commendable, but discouraging reports from the potato salesmen in regard to the quality of these potatoes led the Cornell University Experiment Station to undertake investigations to determine, if possible, the facts. Mr. Gilmore, who is conducting this investigation, has furnished the first years' results, but these are insufficient to permit of deductions being made.

TABLE XI

VARIETY	*Date of Planting*	*Date of Lifting*	*Total Dry Matter*	*Ash in Dry Matter*	*Protein in Dry Matter*	*Starch in Dry Matter*
			Per ct.	*Per ct.*	*Per. ct.*	*Per ct.*
Green Mountain..	May 7	Sept. 11	22.9	4.5	9.77	77.38
Green Mountain..	July 6	Oct. 22	13.1	5.56	11.86	72.43
Doe's Pride.....	May 7	Oct. 20	21.75	5 39	10.35	74.28
Doe's Pride.....	July 6	Oct. 22	19.05	5.10	12.11	71.14

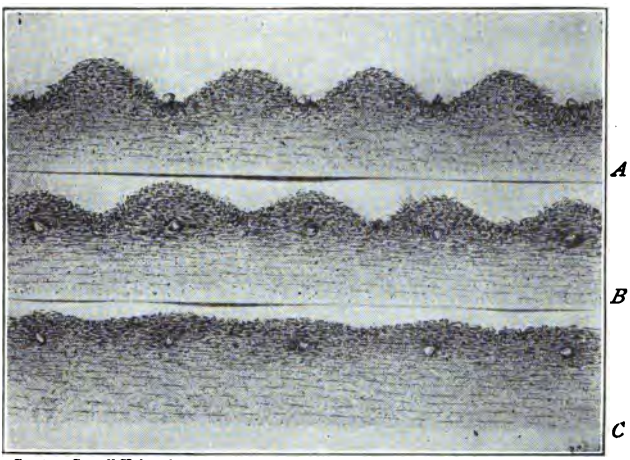
In both cases the late-planted potatoes contained less dry matter and less starch, or, in other words, were more watery, and appeared to be immature. Similar results were obtained during the present year (1904).

Methods of Planting.—The former method and one still quite common is to plant potatoes by hand. A furrow is thrown out by a common plow, or a shovel-plow, and, if applied, the fertilizers, and in

FIG. 24—THE MODERN MANNER OF PLANTING POTATOES

Six acres will warrant the use of a horse planter, and a good one will plant the crop as perfectly as hand labor.

some cases the manure, are placed in the furrow, the potatoes dropped in, and then covered by the plow. Generally speaking, the furrows should be thrown out so that the potatoes will be four inches below ground when the surface is level. The furrows are made the



Courtesy Cornell University.

FIG. 25—PLANTING BY HAND

A—Tuber planted by hand in furrow opened with a shovel or double moldboard plow. *B*—The potatoes covered with shovel plow. *C*—Land harrowed level a few days after planting, to destroy weeds, leaving the potatoes four to five inches deep. Few farmers plant at this depth, even when they mean to do so.

required distance apart. It has been deemed necessary to place the potato in position, and fix it so that it will not move when covered. In England this is done by requiring the planters to press it down by hand, and in this country the potatoes are often stepped on for the same reason. The stepping on them may injure

buds, and hence is detrimental. The rows should be made straight, and care should always be taken to have the potatoes planted in a straight line and at a uniform distance apart. The former facilitates intertillage to such an extent that it is worthy of attention. On a dry, hot day it is inadvisable to open the

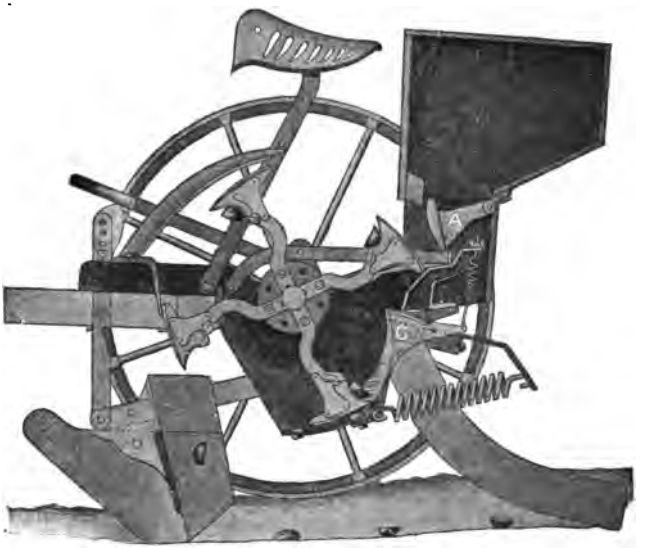


FIG. 26—SECTIONAL VIEW OF ASPINWALL PLANTER

rows much ahead of the planters, and the seed should be covered as soon as possible to prevent loss of moisture. Frequently the rows plowed out before the noon meal hour and left open for this time show the injurious effect of the loss of moisture, especially if the seed is cut. Wherever hand-planting is done and the tubers are not sprouted, the hand-planters, which are

somewhat like hand corn-planters, may be used with profit. They cost $1.00 to $1.50, and it is claimed that an active man can plant at least one acre per day.

Every large grower of potatoes requires a horse-planter. From six to eight acres will warrant the use of such a machine, and it may be made to pay for itself in a short time by hiring it out—preferably with

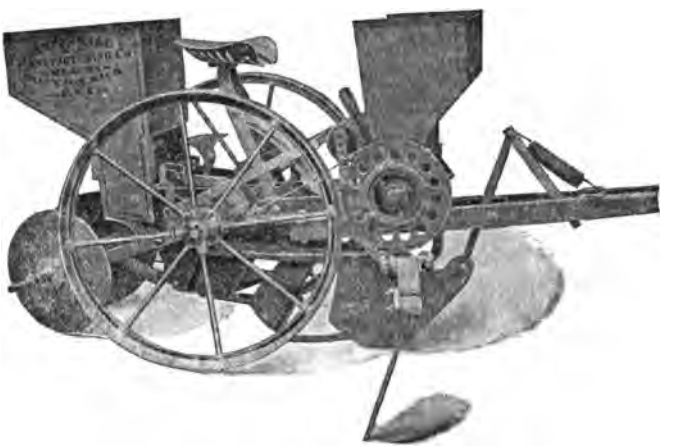


FIG. 27—ASPINWALL POTATO PLANTER (SIDE VIEW)

a man to work it. Some planters require one man, others two men, to work them; the latter generally do the best work, although good work is done by the former. Two systems of mechanism are employed—the picker and the platform. In some planters the tubers are fed from the hopper onto pickers, or spikes, which project from a revolving vertical disk. The disk carries them round to the top of a delivery pipe, where they are knocked off, or fall off, going down the pipe

to the ground. This system, or a modification of it, is used in the Aspinwall (Figs. 26–27), the Deere, and the the Eureka planters. Trials with a planter of this type showed that, with small whole seed and well-prepared ground, this machine will work up to its guarantee of 95 per cent.; that is, it will not skip more than 5 places in 100. With longer cut seed and rougher land, espe-

FIG. 28—THE ROBBINS IMPROVED PLANTER

cially if slightly hilly, it will miss up to 20 in 100. If these misses were distributed it would not be so serious, but often 5 or 6 occur at a stretch. If the seed is cut long and thin, the pickers may take hold of two pieces instead of one. This happens frequently—often up to 20 per cent. These machines open the furrow, distribute the fertillizer, plant the potato, and cover. The latter operation is usually performed by revolving concave disks. The distance apart of the tubers is regulated by adding or removing the pickers. The higher-priced

machines are stronger made than the lower-priced, and, in some cases the fertilizer attachment is extra.

The Robbins improved potato-planter (Fig. 28) is of the platform type. The potatoes are elevated from the hopper by means of a wheel, and are discharged onto a platform which is cleared by several revolving arms (Fig. 29); the mechanism is so timed that a potato

FIG. 29—THE PLATFORM OF THE ROBBINS IMPROVED PLANTER

should fall on the platform between each two arms. Sometimes the elevator comes up empty or brings two pieces up; in either case it is necessary for the man sitting behind to put one piece on the vacant part of the table between the arms or take the extra piece off. In this way the tubers are planted more carefully and regularly than most hand work. The amount and distance apart of seed, and the amount of fertilizer sown, are

regulated by interchangeable sprockets. The various parts of the machine are driven by means of a chain drive. This machine opens the row, distributes the fertilizer in rather a wide stream, plants the potato, and covers it in a satisfactory manner. Any ordinary required depth can be obtained. It can be used for planting beans, corn, and other crops. With potato-planters three to six acres can be planted per day.

Losses of crop due to insufficient seeding cannot be made up during the year. The land requires the same amount of work, and the soil needs moving at digging-time; but there is not the yield, and it is an important consideration whether 5 per cent. to 20 per cent. loss of plants per acre is not too high a price for the sake of one man's pay per day. Even with the cheapest "picker" planter, the lower initial cost is not sufficient to recompense the grower for the loss sustained by using it on ten acres when compared with the perfect machine.

CHAPTER IX

MANAGEMENT OF THE GROWING CROP

Cultivation.—Almost invariably judicious cultivation of potato land is profitable. It is secondary to good preparation of the land. The object is not primarily to destroy weeds, although this may be a consideration. To-day intelligent farmers till to increase yield. Tillage is manuring. No better illustrations of this fact can be found than the tillage experiments of Roberts and others at Cornell University.[1] In these trials potatoes were grown several years in succession, without manures or fertilizers, upon the same land, and yields varying from 300 to 350 bushels per acre, or three to four times the average yield of the State, were secured for several years. This illustrates the value of tillage, but in its entirety is not necessarily a good practice. Tillage destroys humus, and as this is one of the most essential constituents of a good potato soil, a rotation of crops is advised to aid in maintaining the supply. Tillage may be overdone, especially deep tillage in dry weather. During such a time only sufficient shallow tillage should be given to maintain a mulch.

At Cornell from seven to nine cultivations seemed to be most profitable, or about every seven to ten days until the potato-vines meet in the rows. Tillage must be given when necessary. The right number of cultiva-

[1] (N. Y.) Cornell Bul. 140, pp. 389–390; 191, p. 192.

tions will vary with each year and the class of soil. The Ohio Experiment Station[1] found that thorough culture encouraged vigorous growth and aided the plants to resist fungous troubles.

The objects of tillage, then, are:

1. To increase the crop-producing power, presumably by:
   - (*a*) Liberating plant-food.
   - (*b*) Maintaining good texture.
   - (*c*) Conserving moisture by the aid of a soil mulch.
   - (*d*) Pulverizing the ground, so that every shower of rain can enter the soil and not flow off, transporting the fine soil particles.
2. To keep weeds in check.

System of Culture.—*Hills.*—Generally hills—that is, where potatoes are planted in checks—are unprofitable because there are not enough plants per acre and the yield is too low; hence the system is little used unless a piece of land is very weedy.

Drills.—By "drills" it is understood that the soil is thrown toward the potatoes, leaving a depression or furrow between the rows. This system is used for irrigation, when the water flows between the rows. It is also practiced in humid climates, where the temperature does not go high—as, Northern England, Scotland, etc.—and on wet soils and in wet seasons. Often the "furrowing" injures roots and reduces the yield, but many growers claim that the ease with which the potatoes can be dug from drills compensates for any loss in yield. The objection to level culture is that

[1] Ohio Bul. 76, p. 47.

difficulty is experienced in securing machinery which will dig all the tubers.

Level Culture.—In this system the potatoes must be planted a little deeper than in the case of the other two, to reduce the percentage of sun-burned tubers. This system is advocated throughout most of Eastern North America, as, among other things, the quality of

FIG. 30—HALLECK EXPANSIBLE WEEDER

the potatoes is better, owing to the ground being cooler. Its use has been found advisable at such various points as Cornell,[1] Louisiana,[2] North Carolina,[3] Wisconsin,[4] and Arkansas[5] Experiment Stations, while the Maryland[6] Station, in a trial lasting six years, found little difference between level and drill culture, but the slight variation was in favor of level culture.

Method of Cultivation and Tools Used.—About a week after planting the spike-tooth harrow should be run over the land, preferably in both directions, if a mulch is not made by one harrowing. This destroys

[1] (N. Y.) Cornell Bul. 140, p. 390; 156, p. 175.
[2] La. Bul. 22, p. 705.
[3] N. Car. Bul. 85, p. 4; 146, p. 262.
[4] Wis. Report, 1899, p. 210.
[5] Ark. Bul. 50, p. 29.
[6] Md. Bul. 62, p. 204.

young weeds and brings more seed up to germinate, which may be killed by another harrowing a week later. When the potatoes appear, the weeder (Fig. 30) will be found the most serviceable implement for holding the weeds in check and maintaining the mulch. It may

FIG. 31—FIVE-TOOTH CULTIVATOR WITH HILLER ATTACHMENTS
Still used by many farmers.

be driven across the rows after each cultivation until the potatoes are 9 or 10 inches high. As a good horse and man can do twenty acres a day, it is quite expeditious and generally satisfactory.

Generally speaking, it is advised to cultivate widely and deeply from 4 to 6 inches the first, and, in some cases, the second time after the potatoes appear, then reduce the width and the depth to one inch or so.

The first and second cultivations may be given with a five-tooth cultivator (Fig. 31), or a sulky cultivator (Fig. 32) may be used. The spring-tooth cultivator (Fig. 33) is found to be a very useful tool for inter-

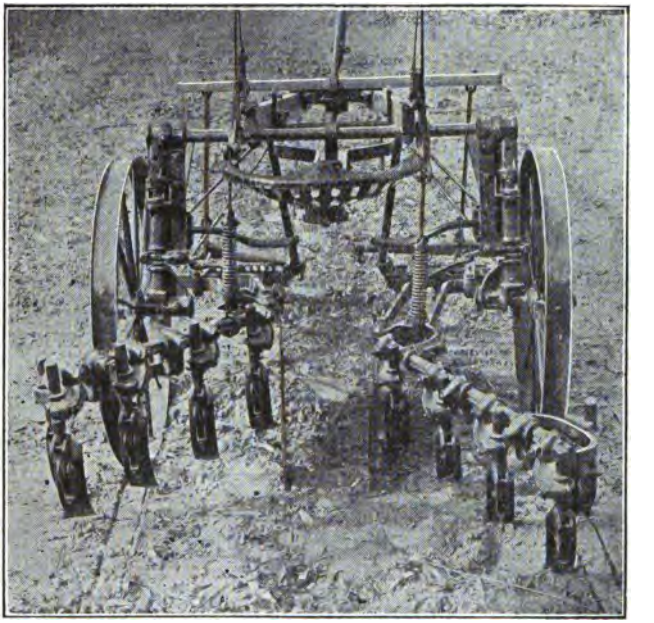


FIG. 32—A USEFUL TWO-HORSE CULTIVATOR
A requisite wherever large areas of potatoes are grown.

tillage work for the third and subsequent cultivations, and the spike-tooth expansible cultivator with the shields is an excellent tool for shallow tillage, as it destroys the small weeds and helps to maintain a soil mulch.

Mulching.—In some districts good yields have been obtained by mulching the land with straw, shavings, pine straw, or some similar substance, instead of cultivating it. Waugh found that it increased the

FIG. 33—ONE-HORSE SPRING-TOOTH CULTIVATOR
An excellent tool for the later cultivations.

yield in Oklahoma[1] and similar results were obtained in New Jersey,[2] while in Georgia,[3] Michigan,[4] Wisconsin,[5] and in my own trials in New York, it was found to be unprofitable, even when the yields obtained were about the same under both conditions.

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[1] Okla. Bul. 15, p. 32.
[2] N. J. Report, 1901, p. 418.
[3] Ga. Bul. 29, p. 348.
[4] Mich. Bul. 95, pp. 13-16.
[5] Wis. Report, 1899, p. 209.

CHAPTER X

OBSTRUCTIONS TO GROWTH AND DEVELOPMENT

THE obstructions to growth may be treated under the following heads:

1. *Season and Climate.*
2. *Weeds.*
3. *Diseases due to parasitic fungi and bacteria.*
4. *Insects.*
5. *Arsenical poisoning.*

1. **Influence of Season and Climate.**—The injurious influence of dry weather at planting-time has already been observed ("Viability," page 66). At the (Hatch)[1] Massachusetts Experiment Station it was observed that the wet condition of the soil at the time of planting appeared to induce the rotting of the young plants just below ground. The occurrence of several extremely hot sunny days in July, following a long rainy period, caused the plants to wilt from the wet condition of the soil and low vitality. No disease was apparent. Probably these plants showed the injurious results consequent on defective respiration due to high temperatures. Frost may cut down early planted potatoes.

Tip Burn.[2]—This is most common in Northeastern

[1] Mass. (Hatch) Report, 1898, p. 52.

[2] Ver. Report, 1899, p 151; Bul. 72, p. 10. (N. Y.) Cornell Bul. 113, p. 309. Conn. Report 18 (1894), p. 133.

America. The leaves become brown on the margin and die. It is caused by drought, and is more prevalent on light soils. Irrigation and selection of vigorous varieties, more care in cultivation, and fertilizing are suggested. At Wisconsin Experiment Station,[1] Green Mountain, Rural New Yorker No. 2, Everett's Heavy Weight, and Colossal proved most resistant in 1896.

Sun Scald.[2]—Its effect is similar to that of tip burn. It is more prevalent in the Southeastern United States, and is often noticed when long-continued damp weather is followed by several hot, bright days.

2. **Weeds.**—These injure the plant by using water and other plant-food, crowding the plant, preventing the free circulation of air, and in these ways reducing the vitality and rendering the potato more subject to disease.

3. **Diseases Due to Parasitic Fungi and Bacteria.**—LATE BLIGHT OR ROT[3] (*Phytophthora infestans*). —There is reason to believe that this disease has existed for ages in the western parts of South America, and was disseminated over Europe a long time before its presence was recognized. It seriously injured the crops of potatoes in the United States and Canada in 1843, and reappeared the following year. In July, 1845, it was first detected in Europe, in Belgium, and within two months thereafter it was recorded in England, Ireland, Scotland, France, Germany, Denmark, and Russia. Since that time it has never been entirely

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[1] Wis. Report, 1896, p. 240. [2] U. S. D. A. Farmers' Bul. 91, p. 10.

[3] (N. Y.) Cornell Bul. 113, pp. 297–302. Vt. Bul. 49, pp. 90, 91; Bul. 72, p. 13. U. S. D. A. Farmers' Bul. 91, p. 8.

absent from the potato crops, although in some years it is not so destructive as in others.

The disease appears during damp, muggy weather in August and September. It is often noticed as small brownish spots on the lower leaves, which rapidly enlarge. In moist weather the edges of these spots, on the under surface of the leaf, appear to be covered with a white downy mildew. In dry weather this may be difficult to detect. Later the leaves appear as though burnt, and finally the whole plant, and in some cases the whole field, will become a putrid, offensive mass of decaying stems and leaves. The tubers may be attacked also, and rot in the field or in storage. Sometimes the disease runs a very rapid course, and a field will wilt down in twenty-four to forty-eight hours.

Cause.—The cause is a parasitic fungus which completes its life history in four or five days or less. The whitish mold is made up of stalks bearing branches (Fig. 34). These bear spore cases (Figs. 34 and 35), which break up to form spores (Fig. 35). These spores send out small tubes (Figs. 35, 36, 37), which enter the potato leaf through a stomata, or breathing pore (Fig. 37), or penetrate the cell wall (Figs. 36, 37). The tubes spread in the walls of the leaf cells (Fig. 34) like mushroom spawn in a mushroom bed, utilizing the plant-food which should go to form tubers. At intervals they send out spore-bearing branches through the stomata (Fig. 34), which perpetuate the trouble. Unless the tubers are well covered with soil, the spores may fall on the ground, and, reaching the tubers, transmit the disease to them.

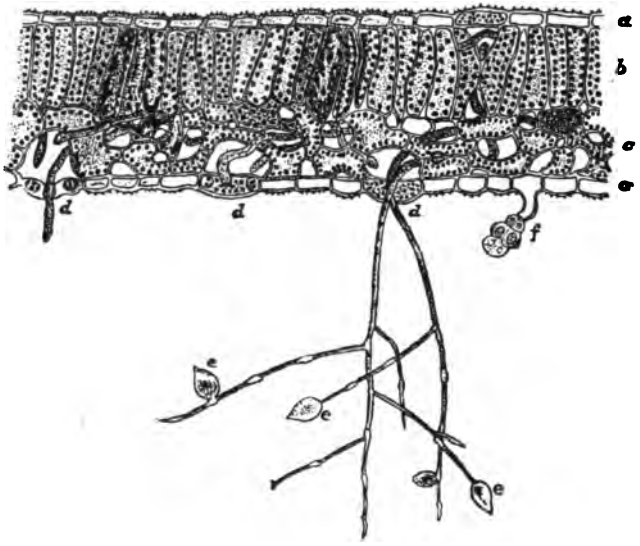

FIG. 34—SECTION OF A POTATO LEAF
(After Marshall Ward)

Showing the parts and the threads, or mycelium, of the blight or rot (*Phytophthora infestans*) *a*—Epidermis, or outer cells. *b*—Palisade cells, which aid in giving rigidity and firmness to the leaf, and in the manufacture of starch and other ingredients. *c*—Spongy tissue, showing cells and large air spaces between. *d*—The stomata, or breathing pores of the leaf, with aerial branches of the parasite growing outward through them. *e*—The spore sacs, or conidia, in which the spores, or seeds, are formed. *f*—A peculiar hair on the under surface of the leaf. The dots in the cells are the chlorophyll granules, which give the green color to the leaf, and aid in the production of starch. The dark parts of the tissue show where cells are dying from the effects of the disease. Loss of cells means a reduction in the amount of food prepared, and, consequently, reduced yield. In New York alone the farmers lose $8,000,000 to $10,000,000 annually from diseases, and because they do not spray. This is the most important disease prevalent at present.

Aids to Attack.—1. Flea-beetles puncture the leaves and furnish easy access for the spores to the inner parts of the leaf.

2. Humid, still days, with a temperature of about 73°

F. Above 78° F. and below 50° F. there is practically no germination of the spores.

Prevention.—1. Spraying with copper compounds—as, Bordeaux mixture, copper sulphate and soda mix-

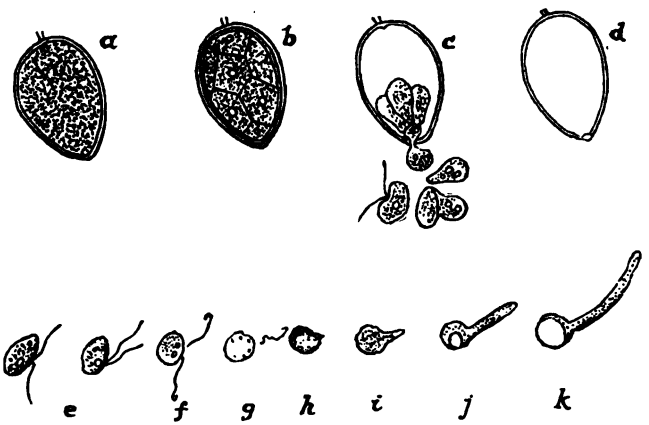

FIG. 35—THE MATURATION OF A SPORE SAC (CONIDIA) AND GERMINATION OF A SPORE (ZOOSPORE) OF ROT
(*Phytophthora infestans*)
(After Marshall Ward)
a—Ripe spore sac in water. *b*—The protoplasmic contents break up into blocks and escape as kidney-shaped zoospores (*c* and *d*). *e*—Each have two thread-like arms, called cilia, which are lost as the spore comes to rest (*f* and *g*); *h*, *i*, *j*, and *k* show stages of germination. Moist, warm, or still, muggy days are best for the growth and development of these spores. On such occasions the disease spreads rapidly.

ture. If the surfaces of the leaves and stems be covered with a thin film of some copper compound, we either prevent the entrance or injure the vitality of the germinating spore tubes, so that the potatoes enjoy a certain degree of immunity from the disease.

This is the philosophy of the use of Bordeaux mix-

ture. The degree of immunity varies with our ability to keep the whole of the plant covered with an armor of Bordeaux mixture. Plants half sprayed are not secure, as the disease can spread rapidly inside the plant. The plant must be completely coated all the time to be immune. This may be impossible when a plant is growing, but this is not the fault of the Bordeaux mixture. The more thoroughly and more frequently the spraying is done the better the chances of bringing the crop through. It will be seen that Bordeaux is but a preventive; it is not a cure. Hence, the poor results from spraying after the disease has obtained a foothold.

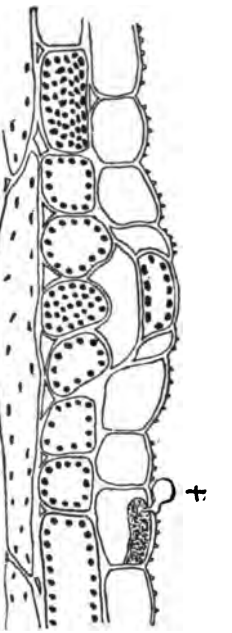

FIG. 36— LONGITUDINAL SECTION OF A POTATO STALK, SHOWING A GERMINATING SPORE OF ROT (*Phytophthora infestans*)

(After Marshall Ward)

The number of stomata per square inch on a potato stem is much smaller than in the case of a leaf, but here the germ tube has pierced the cell wall, and is growing in the cell. In spraying, the stems should be coated with Bordeaux.

2. Obtaining disease-resisting varieties, or changing the seed if it has lost its resisting power.

3. Planting on fresh ground, and planting early.

4. Giving good cultivation, and having a good rotation.

5. Destroying all refuse of potatoes.

6. Having good drainage—both water and air drain-

age. Near woodland, where the air drainage is poor, the disease spreads rapidly on damp or misty days. Land choked with weeds keeps the lower leaves and stalks damp, and more subject to attack.

FIG. 36—THE GERMINATING TUBE OF A SPORE OF ROT (*Phytophthora infestans*)

(After Marshall Ward)

This may enter a plant through a stomata, or breathing pore, as at *a*, or it may penetrate the cell wall, as at *b*. The maintenance of a coat of Bordeaux mixture all over the plant would check the growth of these spores.

7. Not digging until ten days after the vines die.

8. Getting potatoes out of the field as soon as dug, and never covering piles of potatoes with spore-laden haulm.

EARLY BLIGHT,[1] OR LEAF SPOT DISEASE (*Macrosporium solani*).—It is a fungus disease which appears usually in June to July, or ahead of the late blight. It does not generally attack vigorous plants. It spreads in warmer, drier weather than the late blight. It forms circular brown spots with target-like markings on the leaves. It enters the leaf through tissues weakened by other agents, as flea-beetles, etc. It does not attack the tubers directly, and never causes them to rot.

Preventives.—1. Spraying with Bordeaux mixture.

2. Selection of vigorous varieties.

3. Better tillage and fertilization.

POTATO ROSETTE (*Rhizoctonia solani.*[2])—This disease has been known since 1842, but it is only recently that it has caused considerable trouble. It is now well established all over the country, and in some places 90 per cent. of the tubers appear to be affected by it. It tends to cause the formation of an abnormal number of small tubers of no value. The stems show discolored decaying areas above ground and brown dead areas below, and the leaves tend to grow in rosette-like clusters. The resting spores live for several years in the soil, and the methods of infection are by seed potatoes, beet and mangold roots, dead potato stems, and some weeds; hence, fields should be kept clean. The disease attacks beets, mangolds, and clover. Soaking the seed in formalin will destroy the spores on the potatoes, but is of no value if the soil is infected. Planting sound

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[1] Vt. Bul. 49, pp. 91–96; Bul. 72, pp 16–25. U. S. D. A. Farmers' Bul. 15, pp. 4, 5; Bul. 91, p. 5. (N. Y.) Geneva Bul. 123, p. 236. N. H. Bul. 45, pp. 50, 56. Tex. Bul. 42, p. 923.

[2] (N. Y.) Cornell and Geneva Bul. 186. Col. Bul. 69, 70. Ohio Bul. 139, 145.

tubers and a good rotation of crops will aid in combatting the trouble.

SCAB (*Oopsora scabies* Than.).—Thaxter has shown that this fungus is the chief cause of scab (Fig. 38), although Rozé claims that the primary cause is bacterial, and that the fungus *Oospora scabies* and other organisms follow, causing the familiar rough and cankerous appearance of scab. Other causes are also given.[1] An enormous amount of work has been expended on this disease, and still no absolute preventive is known if the land is inoculated with the trouble.

Treatment.—Of a large number of substances used for treating the seed potatoes, soaking them in a solution of formalin, 1 pound to 30 gallons of water, for 2 hours is the most effective. Soak the potatoes before cutting them, and if they are not planted at once spread them thinly to dry. If left in bags they will heat and the buds be ruined. After soaking two or three lots of potatoes the solution should be changed, as it loses its efficacy. A big cheese-vat or sheep-dipping vat, in which several bags may be placed at a time, is useful. A small block and tackle will enable one man to lift large bags in and out of the vat, and suspend them to permit of some drainage.

The following points are of importance.

An acid condition of the soil is injurious to the growth of scab. Lime, wood ashes, and barn manure aid the growth of scab, while sulphate of ammonia, muriate of potash, sulphate of potash, kainit, acid phosphate, and dissolved bone render the soil less favorable

[1] W. Va. Special Bul. 44, pp. 285–6.

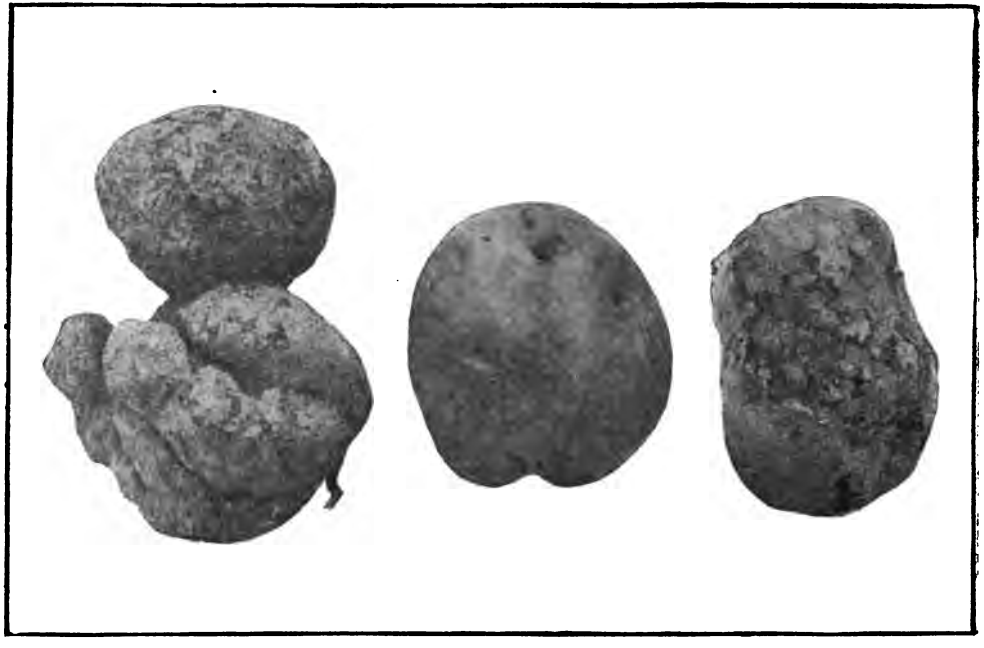

FIG. 38—TUBERS WITH AND WITHOUT SCAB

Centre one free from disease. The one on the left shows second growth also. (*See pages* 85, 118.)

to the disease. Scabby seed will inoculate clean land. Scabby potatoes cannot be sold. If used as fertilizer, even after steaming for twenty minutes[1] or being exposed to the weather all winter, they will inoculate the land they are spread on.

Exposing tubers to sunlight for four weeks before planting reduces the percentage of scab and hastens growth.

Scab can live in the soil at least six years without a known host. Beets, mangolds, turnips, and rutabagas are subject to the same disease; hence in the rotation these crops should be avoided, if possible.

Varieties vary in their susceptibility to scab,[2] the thicker skinned varieties being reported as most resistant.

It seems to be useless to treat scabby seed if they are to be planted on scab-infested land.[3]

Plowing under green rye does not diminish scab, as has been stated.[4]

Applying sulphur in the rows at the rate of 300 pounds per acre and more has been tried extensively, but is not recommended as a practice, as it is of little use on infested land.

Diseases in Storage.—WET ROT has several causes.

1. Blight or Rot (*Phytophthora infestans*). The tissues of the tuber become soft either partially or wholly, the skin shrinks, and the layer under it becomes pasty. Potatoes from light soils appear to be

[1] N. J. Report, 1899, pp. 344–345. [2] N. J. Report, 1899, p. 329; 1900, p. 417.
[3] (N. Y.) Geneva Bul. 138, p. 631.
[4] (N. Y.) Geneva Bul. 138, p. 629. N. J. Report, 1900, p. 417.

less subject to it than those from heavy soils, and the disease spreads most rapidly in a damp, warm, and close cellar.

2. Due to bacteria.[1] The tubers may be wholly or partially soft, and exhale a disagreeable odor. Butyric acid may be liberated and the destruction of the tubers is slow. Contact with other potatoes should be avoided.

If to be used for seed, in some cases depending on the cause, soaking the tubers in formalin before planting is beneficial.

DRY ROT may be the evidence of the presence of one or more of several troubles.[2]

1. Stem rot,[3] bundle blackening, dry end rot, is believed to be due to a fungus (*Fusarium oxysporum*); the leaves curl, and the foliage wilts and dies. The tubers show brown or blackened bundles at the stem end under an apparently sound skin. The disease spreads rapidly in storage, especially if the rooms are warm. Some investigators advise that diseased tubers should not be fed to stock, thrown on the manure-pile, or planted, and that all such potatoes should be destroyed at harvest-time or as soon as discovered. No remedy is known.

2. Due to bacteria. The tubers may be free from odor, moderately firm, but more or less soft in spots, showing in places a loose skin, which yields to the finger, and under which are white, gray, or brownish blotches. Soaking unaffected tubers in formalin before planting is suggested.

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[1] Ill. Bul. 40, p. 140. [2] Ill. Bul. 40, p. 139. Tex. Bul. 42, p. 926.

[3] U. S. D. A. Bureau of Plant Industry Bul. 55. (N. Y.) Geneva Bul. 101, pp. 83, 84; Bul. 138, pp. 632, 634.

4. **Insects.**—THE FLEA-BEETLE (*Crepidodera* (*Epitrix*) *cucumeris*) (Fig. 39).—These small insects often cause more loss than the potato beetles. They perforate the leaves (Fig. 40) during a critical period of the plant's life. The holes produced are used by the spores of both early and late blight for entrance into the leaf. Arsenical poisoning is usually first noticed on the margins of these holes. At no time in their life history can these insects be readily destroyed. They dislike Bordeaux

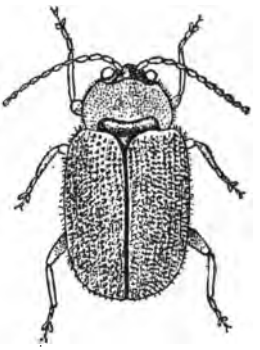

FIG. 39 — THE CUCUMBER FLEA-BEETLE (*Crepidodera* (*Epitrix*) *cucumeris*)
(After Chittenden)
Highly magnified. The insect is barely one-eighth inch long. The damage done by this insect is considerably underestimated.

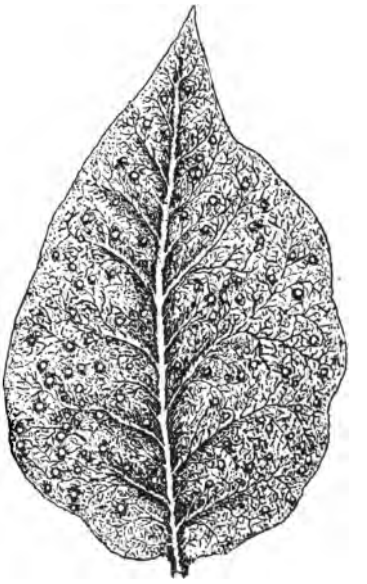

FIG. 40—LEAFLET OF POTATO, SHOWING OVER A HUNDRED HOLES MADE BY FLEA-BEETLES
The ease with which this damage might be overlooked is evident. These holes make suitable avenues for the entrance of spores of disease, and pave the way for the rapid destruction of the plant.

mixture; hence, the only known means of reducing their ravages is to spray the plants with this material.

NUMBER OF FLEA-BEETLE PUNCTURES IN 50 LEAFLETS FROM 12 ADJACENT ROWS [1]

	Punctures
Row 1.—Sprayed with very weak Bordeaux mixture	1,794
Row 2.—Sprayed with very weak Bordeaux mixture and soap	1,071
Row 3.—Not Sprayed	2,511
Row 4.—Sprayed with strong Bordeaux mixture	1,194
Row 5.—Sprayed with strong Bordeaux mixture and soap	1,090
Row 6.—Sprayed with weak Bordeaux mixture	1,293
Row 7.—Sprayed with weak Bordeaux mixture and soap	901
Row 8.—Not sprayed	2,287

The grubs of the flea-beetle infest the tubers and roots of potatoes, doing some damage and causing the trouble known as "pimply potatoes."[2]

In the Pacific Coast the flea-beetles (*Epitrix subcrinita*, Lec., and *E. hirtipennis*, Mels.) sometimes reduce the yield 50 per cent. by their ravages. As they are leaf-eaters, the foliage should be sprayed or dusted with an arsenical poison. One pound of Paris green to 150 gallons of water per acre is suggested,[3] but it is better to apply the Paris green in Bordeaux mixture.

THE POTATO BEETLE, COLORADO POTATO BEETLE, OR POTATO BUG (*Doryphora decemlineata*).—Until 1850 this insect was confined to Mexico and the Rockies. In 1859 its eastward movement was noted, and it is now well distributed. A related species (*D. juncta*)

[1] Vt. Bul. 72, pp. 6–9.
[2] (N. Y.) Geneva Bul. 113, pp. 312–317.
[3] Cal. Bul. 135, p. 29.

retreated before its advance, and is now more common in the South. In New Mexico[1] a parasite lives on the eggs and larvæ. The eggs are laid on the potato leaves, on which the young "bugs" live, chewing holes in or eating the whole of the leaf. The insects are most active about blossoming-time, and do considerable damage if left alone.

Modes of Combatting.—The leaf should be thoroughly coated with a poison, generally an arsenical compound being used. The poison should be applied as soon as the "bugs" hatch, because the younger the "bugs" the more easily they are destroyed. Various arsenical compounds are used—as, Paris green, arsenate of lead, and others. "Bugs" object to Bordeaux mixture, hence in applying the poison it is found to be good practice to apply Bordeaux mixture at the same time. The whole of the plant should be covered, because if badly sprayed the bugs live on the unsprayed foliage. The standard application is ¼ to ½ pound of Paris green to 50 gallons of mixture. Generally 1 pound of Paris green is sufficient per acre, and if it is desired to apply more than 100 gallons, the proportion of Paris green should be varied accordingly. If desired, Paris green may be applied in the dry form by means of a powder gun, the Paris green being mixed with flour, land plaster, etc., as desired. About 50 cents per acre should cover the cost of one application.

THE POTATO WORM,[2] also known in the South as the tobacco-leaf miner (*Gelechia operculella*, Zell.), is estimated to destroy 25 per cent. of the potato crop

[1] *American Naturalist*, 1899, pp. 927–29. New Mexico Bul. 33, pp. 47–51.
[2] Cal. Bul. 135, pp. 5–29.

on the Pacific Coast. Great losses often occur in storage as well as in the field. The moths fly at night, and lay eggs on the stalks and tubers. Destruction of the moths by trap lanterns, the destruction of infested stems, careful hilling of potatoes, getting them under cover as soon as dug, cleaning up the refuse of the field, and a rotation of crops is recommended. In storage, fumigation with 1½ pounds of carbon bisulphide per thousand cubic feet of air-space will destroy all the larvæ if repeated five times at intervals of two weeks. This gas is inflammable, and no lights must be taken near. It is a heavy gas, and sinks from the top of the building.

POTATO STALK WEEVIL[1] (*Trichobaris trinotata*).—This beetle attacks the stalks, causing them to wilt. It is found from Canada to Texas and Florida. The vines should be destroyed as soon as attacked, and weeds belonging to the potato family kept down.

Another insect has caused similar trouble in Maine.[2]

GRASSHOPPERS (*Melanoplus* sp.) do much damage during some seasons, especially after the hay crop is cut, by severing parts of the leaves. Bordeaux mixture containing an arsenical poison is the best deterrent, being better than the arsenical compound alone.

THE JUNE BUG (*Lachnosterna* sp.).—The big white larvæ of these beetles often eat the tubers. They are most prevalent on land which has been in grass, although if land is in clover but one or two years less trouble may be expected.

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[1] Consult U. S. D. A. Div. of Entomology, Bul. 33, 6. Ind. Report, 1895. Kan. Bul. 82. Pa. D. A. Report, 1896. N. J. Bul. 109, pp. 25–32.

[2] Me. Report, 1897, p. 173.

Wireworms injure potatoes by boring through them. They are more prevalent on land which has been in grass a few years. Frequent rotation and fall plowing are advised for both of these pests.

Other insects injurious to potatoes include: Striped Blister Beetle, or "Old-fashioned Potato Bug" (*Epicauta vittata*). This insect should be combatted in the same way as the Colorado potato beetle—by applications of arsenical poisons to the foliage. The Tomato Worm and Cutworms are injurious. The latter are very destructive at times, and the best remedy seems to be to place bait, made of moist bran and sugar, poisoned with Paris green in the fields.[1]

Arsenical Poisoning.—Paris green, London purple, and other arsenical compounds usually carry their arsenic in an insoluble form, but some may be soluble. This soluble arsenious oxide may burn the leaves, especially the tips where the mixture flows, and the edges of mutilated leaves, causing death of the spot and a "target-like" appearance of the leaf.

Remedy.—Do not use more than 1 pound of Paris green per acre, dissolved in 100 to 200 gallons of Bordeaux mixture. The trouble is most prevalent where people half spray and use Paris green alone, or 1 pound of Paris green in one barrel (50 gallons) of water and lime or Bordeaux mixture.

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[1] N. J. Bul. 109; Report, 1895, p. 366.

CHAPTER XI

SPRAYS AND SPRAYING

FUNGICIDES are materials used to combat fungi, or small plants which are usually parasitic.

Bordeaux mixture is the leading fungicide for potatoes. The ingredients for making this mixture are freshly slaked lime and copper sulphate. The fungicidal value lies in the copper compound. The lime is added to prevent the copper sulphate burning the foliage, and to make the mixture more adhesive and more readily seen when applied. The amount of lime and copper sulphate used vary considerably. Not less than 2 pounds of lime can be used to 3 pounds of copper sulphate. Excess of lime is disadvantageous in some ways, as it renders the mixture less efficient by making it thicker, and in this way more liable to settle[1] and more difficult to apply, causing nozzles to clog, but in a wet season an excess of lime is desirable. A thin mixture can, however, be more uniformly applied.

Use freshly burnt, clean, firm lime; slake it by pouring water, preferably hot, over it in small amounts at a time, until the lime has fallen to a fine powder; then add enough water to make a thin paste. A large quantity of lime may be slaked at one time and kept covered with water. This is a "stock solution."

To dissolve copper sulphate, it should be placed in a

[1] (N. Y.) Geneva Bul. 243, p. 320.

coarse sack and suspended in the top of the water in a wood, brass, or porcelain vessel—usually a wooden barrel, as it corrodes iron. The copper sulphate sinks in the water as it dissolves, and a gallon of water will dissolve 3 pounds of copper sulphate. This is a saturated solution. If 6 pounds of copper sulphate are required to a barrel of water, 2 gallons of this stock solution should be used.

Mixing.—It is economical to have an elevated stage, under or alongside of which the spray-cart may be drawn. Place four 50-gallon barrels on this stage, two of which are for the stock solutions of lime and copper sulphate, and two for making the mixture. To make 50 gallons of Bordeaux mixture, pour 2 gallons of copper sulphate saturated solution into one barrel and fill it up to the 25-gallon mark with water. Stir up the stock solution of lime and dip out as much as is required; if 5 pounds, then the solution equivalent to this amount; strain it, to exclude particles which might clog nozzles, into the lime-mixing barrel, and fill up to the 25-gallon mark and stir. The mixing-barrels should be provided with 2-inch or 3-inch rubber hose, one end of which is attached in an opening near the bottom of the barrel, the other free. When ready, put the hose from each barrel into the spray-tank, and let them empty and mix together. The rubber hose should be long enough so that the free end can be turned over into its barrel when not in use. If desired, the stock-solution barrels may be placed above and over the mixing-barrels, so that dipping out solution is avoided; it may be run out through a faucet. Convenience to a water-supply expedites the work.

Testing Bordeaux Mixture.—In practice little attention is paid to the quantity of lime, except that sufficient is added to combine with all of the copper sulphate. To determine when this has taken place the potassium ferrocyanide test is made. Purchase ten cents' worth of potassium ferrocyanide, or yellow prussiate of potash, and dissolve it in water. Label it "Poison." Stir the Bordeaux mixture in the spray-tank and take out a sample in a small vessel, to which add a drop of potassium ferrocyanide. If no change in color is noted where it dropped there is sufficient lime, but it is better to add lime solution equivalent to a pound of lime more. If the drop changed the color of the solution reddish brown it shows that there is not enough lime.

Strength of Solution. — For potatoes, 1 pound of copper sulphate to 7 or 8 gallons of water is commonly used; that is:

Copper sulphate (blue vitriol), 6 pounds.
Quicklime (not slaked), 4 to 6 pounds.
Water, 48 to 50 gallons.

Bordeaux Dust,[1] or Dry Bordeaux Mixture, can be made in two ways:

1. Slaking the lime by pouring a strong solution of copper sulphate over it.

2. Mixing the strong copper sulphate solution with freshly slaked lime which has been made into a paste, then placing the mixture in a bag and drying and pulverizing it. The two ingredients must be well mixed and passed through a fine sieve. Dry Bordeaux is offered for sale under various names. Adler's Bor-

[1] For details, see Missouri Bul. 60. (N. Y.) Geneva Bul. 243, p. 325.

deaux is reported to be as efficient as newly mixed,[1] but generally these preparations are much inferior to the newly prepared, and, when applied dry, are less effective than in the wet form.

Washing Soda and Copper Sulphate Mixture.—This mixture is being used with success in parts of Europe. It does not clog nozzles, spreads evenly over the leaf, and is easily and cheaply prepared. The washing soda is dissolved in water, poured into the barrel of water and stirred, and the copper sulphate added and stirred. Various strengths are in use, but the most satisfactory one for American conditions has yet to be determined. We are trying 4 pounds of copper sulphate, 6 pounds of washing soda, and 50 gallons of water, adding 1 pound of lime if Paris green is used. A little over 1 pound of washing soda might be sufficient to neutralize the 4 pounds of copper sulphate, but it is safer to use more. In Ireland 5 pounds are used and for three successive years in extended trials this mixture has given better results than Bordeaux mixture.[2] At (N. Y.) Geneva Station, in 1904, it was not so good as ordinary Bordeaux mixture.

Spraying with Bordeaux Mixture.—*Benefits.*—Spraying with Bordeaux mixture influences the potato crop in the following ways:

1. The structure[3] of the leaf shows a slight increase in thickness and in strength, and so offers more resistance to the growth of disease spores.
2. The chlorophyll,[3] or green coloring matter of the leaf and stem, is increased.

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[1] Me. Bul. 73, p. 55. [2] Department of Agric. for Ireland Leaflet, 14.
[3] Frank & Krüger. E. S. R., VI., p. 306.

3. The transpiration[1] of moisture is greater in sprayed plants. Food is moved from the roots to the leaves in water, the food is worked over, and the water is given off. The more food-laden moisture passing through, the greater is the growth.
4. The assimilation[1] or taking in of food from the air by the leaves is much greater.
5. The duration[1] of the leaves and vines[2] is greater.
6. The growing period[3] is extended (Fig. 41), insuring a heavier yield. In Vermont blight often appears in August, and from then on the potatoes have grown 50 bushels a week when the foliage was preserved.
7. The tuber production[1] is increased, due to increase in the size of the tubers[4] and the number of tubers per plant. Jones & Morse,[5] of Vermont, show that the average yield for thirteen years (1891 to 1904), without spraying, was 171 bushels per acre, while the sprayed plats yielded 286 bushels per acre, or an average annual gain of 115 bushels per acre.
8. The dry matter[6] is increased.
9. Starch formation[1] in the tuber is considerably increased. At Geneva, (N. Y.) Experiment Station[6] an increase of 7 per cent. was obtained.
10. Where there is no disease[7] the yield may be in-

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[1] Frank & Krüger. E. S. R., VI., p. 306 [2] Vt. Report, 1899, p. 156.
[3] Vt. Bul. 40, pp. 26, 27; Report, 1899, p. 272. Can. Exp. Farms Report, 1901, p. 120.
[4] (N. Y.) Geneva Bul. 221. [5] Vt. Bul. 106, p. 231.
[6] (N. Y.) Geneva Bul. 221.
[7] E. S. R., Vol. IX., p. 765. (N. Y.) Geneva Bul. 123, p. 234.

Courtesy (N. Y.) Geneva Station

FIG. 41—SPRAYED AND UNSPRAYED PORTIONS OF A NEW YORK POTATO FIELD (Taken October 3, 1903.) Spraying extends the growing period, thus insuring a heavier yield.

creased by spraying, due to increased vigor of the plants. At the Vermont Experiment Station,[1] in 1900, the yield was increased 73 bushels per acre by spraying, although blight did not appear that year.

Time of Spraying.—Thoughtfulness, thoroughness, and timeliness are essential to success. A man must watch his crop, the season, and conditions; know for what he is spraying, and do it intelligently as well as thoroughly. In wet years spraying should begin earlier than in dry. The first spraying should be given early enough to ward off the first attack. At Vermont Experiment Station, in 1900,[2] three applications were most economical, but the first one, that of July 26, was the most important, as half the entire gain was due to it; the sprayings on August 17 and September 8 were of about equal importance. At the same station,[3] in 1903, one timely spraying on August 10 insured a gain of 124 bushels per acre. Some growers who sprayed twice in July secured little benefit, because by the time the blight appeared, the latter half of August, their plants were unprotected. No rule can be given; each man must watch for himself. In some districts it is profitable to give the first spraying when the plants are 6 inches tall, and repeat every ten to fourteen days, or as conditions demand.

Number of Sprayings.—At (N. Y.) Geneva Experiment Station,[4] in 1903, spraying potatoes five times gave an increase of 30 bushels per acre over three times, and three sprayings increased the yield 88 bushels per

[1] Vt. Report, 1900, p. 272.
[2] Vt. Report, 1900, p. 273.
[3] Vt. Bul. 106, p. 231.
[4] (N. Y.) Geneva Bul. 241, p. 262.

acre over no spraying. At Cornell Experiment Station[1] one application of Bordeaux mixture, and three of Bordeaux mixture and Paris green, increased the yield 103 bushels per acre, while another year six sprayings increased the yield 48 bushels per acre. At Vermont Experiment Station[3] two applications have in general proved most profitable. The (N. Y.) Geneva Experiment Station recommend, as the result of their trials to the year 1904, that spraying commence when the plants are 6 to 8 inches tall and thorough applications to be made at intervals of ten to fourteen days during the season, making five to seven applications in all.

Insecticides are materials used to destroy injurious insects. Poison is spread on the leaves to destroy leaf-eating insects, and materials that kill by contact are used against insects that suck plant-juices. For poisoning the first class there are on the market a number of preparations, which may be grouped as follows:[4]

1. *Standard Remedies.*—Scheele's Green, Paris Green, London Purple, Hellebore.
2. *Commercial Substitutes.*—Paragrene, Green Arsenoid, Green Arsenite, Pink Arsenoid, Laurel Green, Arsenate of Lead, Disparene.
3. *Home-made Remedies.*—Arsenite of Lime, Arsenite of Soda, Arsenate of Lead, Arsenite of Lead.
4. *Proprietary Remedies.*—Bug Death,[5] Black Death,[5] Hammond's Slug Shot,[5] Quick Death, Knobug,

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[1] (N. Y.) Cornell Bul. 140, p. 402. [2] (N. Y.) Cornell Bul. 196, p. 48.
[3] Vt. Bul. 106, p. 230. [4] From (N. Y.) Geneva Bul. 243, p. 329.
[5] For analysis, see (N. Y.) Geneva Bul. 190, p. 289.

etc. In most of these the amounts of arsenical compounds present is small.

Contact Remedies—Standard.—Whale Oil Soap, Carbon Bisulphide, etc.

While some of the poisons in Group 4 (proprietary) have value, they are too expensive, and the work of various experiment stations shows that Paris green or arsenate of lead are cheaper and generally much more effective poisons.[1]

Paris green rarely occurs on the market pure. In New York the law requires that it contain 50 per cent. of arsenious oxide or white arsenic. Often some of this arsenic is soluble in water, and in such cases it is liable to burn foliage. If more than 4 per cent. of water soluble arsenic is present the sample should be condemned.

Paris green tends to sink to the bottom of the spray-barrel; hence, unless kept well stirred, the concentrated solution applied at the last may burn the foliage. It should be applied at the rate of about 1 pound per acre, in not less than 100 gallons of Bordeaux mixture. When applied dry, mix 1 pound of Paris green with 50 pounds of land plaster, flour, slaked lime, or any other dry powder.

At (N. Y.) Geneva Experiment Station, in 1904, Paris green was applied to potatoes at the rate of 3 pounds per acre in 150 gallons of water. Four applications were made during the season, and no injury to the foliage occurred. The results show that Paris green is of distinct fungicidal value, and that it in-

[1] Me. Bul. 68, 87, 98.

creased the yield of potatoes from 175 bushels per acre, on plats where bugs were removed by hand, to 221 bushels per acre, and that it was better applied in water than in lime water.

Lead Compounds.—Insoluble arsenate and arsenite of lead are recommended because they contain no injurious soluble arsenic, a heavy dose will do no harm, they lead all other materials in remaining in suspension, they adhere to the foliage, and they can be easily made at home and their purity insured. The articles required are sugar of lead (acetate of lead), costing 7¼ cents per pound, wholesale, and arsenate of soda, costing 5 cents per pound, wholesale, at present. They may be dissolved in cold water, but for quick solution hot water is better. The formula for making 1 pound of arsenate of lead—enough for 100 gallons—is:

Dissolve 24 ounces of sugar of lead in 1 gallon of cold water, and 10 ounces of arsenate of soda in 3 quarts of water, both in wooden vessels.[1] When dissolved, pour together into the spraying-tank. Prepared in this way, it is superior to any ready prepared sample. Of the latter there are several makes, which may be used if but a small amount is required. "Swift's Arsenate of Lead" may be purchased in a white powder form or as a paste; it is easily mixed with water, but both forms settle more quickly in the spray-tank than the freshly made. Disparene retails at 25 cents per pound, and is a heavy white paste which finally mixes well with water, but takes some time.

[1] Cal. Bul. 151. (N. Y.) Geneva Bul. 243.

It has great adhesive power, and will not burn foliage. The Adler lead compounds are similar.

Arsenite of lead is made by dissolving separately 12 ounces of sodium arsenite and 4 pounds of sugar of lead, then pouring them into 150 gallons of water. The home-made mixture remains in suspension longer than the prepared. Pink arsenoid is arsenite of lead colored; it is no more dangerous to foliage than Paris green, and is cheap. It will remain in suspension about twice as long as Paris green.

Green arsenoid (copper arsenite) sometimes contains considerable soluble white arsenic, and is then dangerous to foliage, especially in a dry climate or time.

White arsenoid (barium arsenite) is dangerous to foliage.

Calco green and laurel green do not contain enough arsenic to render them of much value, and some samples cause serious injury to foliage.[1]

Paragrene is a prepared compound containing, in some cases, considerable soluble "white arsenic," which is objectionable.

Arsenic and lime is a cheap mixture. Boil 1 pound of white arsenic, costing 7 cents per pound, with 2 pounds of lime in 2 gallons of water for forty minutes and add to 150 or 200 gallons of water. It cannot be safely applied alone, even with the addition of considerable lime, but may be used in Bordeaux mixture. The copper sulphate in the Bordeaux mixture seems to prevent the caustic action. If the lime and arsenic fail to combine, the mixture is dangerous.

[1] Vt. Report, 1899, p. 271. Cal. Bul. 151, p. 24.

Cost of Spraying and Profits Derived.—In 1903, at the farm of J. V. Salisbury & Son, Phelps, N. Y., the total expense of spraying[1] 14 acres five times was $55.76, the items being as follows:

504 pounds of copper sulphate, at 6 cents	$30.24
8 bushels of lime, at 35 cents	2.80
12 pounds of white arsenic, at 5½ cents	.66
55 hours' labor for man, at 17½ cents	9.63
47 hours' labor for team, at 17½ cents	8.23
Wear of sprayer	4.20
	$55.76

Cost of spraying per acre for each application was 80 cents.

	Bushels
Yield of sprayed rows, per acre	147
Yield of unsprayed rows, per acre	83
Increase in yield per acre	64

A good showing, considering that there was no blight this year.

64 bushels per acre on 14 acres (896 bushels), worth	$448.00
Less cost of spraying	55.76
Net profit on 14 acres	$392.24
Net profit per acre	28.01

Mr. Salisbury sprayed potatoes for his neighbors at 80 cents per acre and furnished everything. In other experiments conducted in 1904 by the Geneva Experiment Station, the cost of each application was as low as 61 cents per acre, and the net profit as high as $60.00 per acre.

[1] (N. Y.) Geneva Bul. 241, p. 275.

Spraying Machines.[1]—A spraying outfit consists of a pump, nozzle, agitator, tank rods, hose, crop-spraying attachments, etc. They are made in various sizes, and are known as knapsack, carried and worked by a man; barrel, hauled by man or horse (Fig. 42), and worked by manual labor; and power sprayers, in which the pumping is done by gearing from the wheels, steam

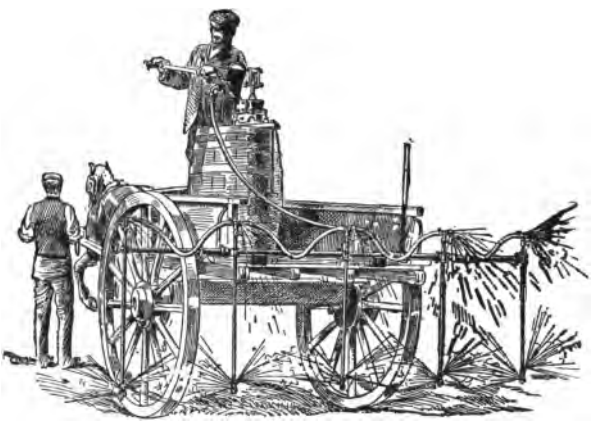

FIG. 42—A SUGGESTIVE ENGLISH SPRAYING MACHINE

Emphasis is laid upon coating the under surface of the leaves, and experiments show that it is profitable to do so under British conditions.

or gas engines, compressed air or carbon dioxid. The pressure is generated in the pump; 100 to 120 pounds pressure per square inch gives a much finer spray than 50 to 60 pounds. The power sprayers give the former, the manual labor sprayers rarely exceed the latter. The working parts of the pump should be of brass or bronze; rubber or leather valves, or any parts that Bor-

[1] Consult Mo. Bul. 50 and (N.Y.) Geneva Bul. 243.

deaux mixture will corrode, are inadmissible. The pump should be easy to clean.

The nozzle and the pressure determine the character of the spray. The Vermorel type of nozzle is one of the best; it does good work at a low pressure of 50 to 60 pounds, but better work at 100 pounds. It does not throw the spray a great distance. The nozzle used should permit of being readily cleaned.

The agitator may be (1) mechanical or (2) the jet type. The former is generally used and considered more efficient, dashers being used in barrel outfits and whirling paddles in large tanks. The jet type returns a stream of solution from the pump to the bottom of the tank. It can be made efficient on power sprayers, but deficiency of power bars their use on hand outfits.

Tanks.—Cypress, pine, and cedar are used in making tanks, the first being considered best. Their capacity varies from 50 to 250 gallons.

Hose.—The hose should withstand a pressure of 125 pounds per square inch. Three and four ply are most used. Some prefer five and six ply. Half-inch hose is most commonly used; some prefer three-eighths of an inch.

Crop-spraying Attachments.—The potato spraying attachment should carry two or more nozzles for each row. These should be capable of being turned upward when not in use, to prevent their clogging with sediment while drying. The spray should be thrown upward and sideways, to coat the under surface of the leaves as well as the upper surface. From two to six rows are sprayed at a time (see Frontispiece and Fig. 42), and the attachment should fold or turn up to

facilitate turning or going through a gateway. Stationary nozzles cannot direct the spray so well as hand nozzles; hence, more should be put on to make sure that the plants are coated. The cost of the extra amount of mixture is small compared with the cost of the labor used in applying it.

CHAPTER XII

HARVESTING

Digging.—Early potatoes may be dug as soon as large enough. For late varieties which are to be stored it is necessary to wait until the tubers have attained full size, the haulm and leaves have died, the tubers come freely from the stem and have not to be jerked off, and the skins are firm and will not come off easily when rubbed. If the vines have been destroyed by blight the potatoes should not be dug until at least ten days after the vines are dead, as there is then less liability of rot in storage.[1] If frost sets in early and the growing season has been late, it may be necessary to dig before the potatoes are quite mature. In this case the shrinkage in weight, if stored, will be greater than if they had matured, and a reasonable offer for them straight from the field should not be declined. For storage, potatoes must be dug when dry, picked up at once, and kept cool. If possible, haul to some cool place at once, and let them cool all night before placing in storage. This is impossible where large quantities are grown, and in such cases good ventilation of the storage-place must be given to reduce the temperature as quickly as possible.

Methods of Digging.—1. *By Fork, Spade, or Potato-hook.*—The early potatoes are often dug by hand because they are so easily injured. The skin is

[1] Vt. Bul. 106, p. 233.

tender, the tubers adhere to the stem, and often require removal. It is a slow, tedious process, but nearly every potato is obtained. A man will dig one-eighth to three-eighths of an acre a day. With the main crop a man will dig from one-tenth to one-half acre a day at a cost generally varying between two and six cents per bushel, sometimes running to eight and occasionally lower than two cents, depending a great deal on the skill of the man, the yield, the soil, and state of the land. As weather conditions may retard digging, and labor is hard to obtain, this method is being discontinued except on small patches.

2. *Plow.*—Plowing out with a common plow, or a potato plow, or so-called "digger," many of which are:

Modified Shovel Plows.—All that I have tested have been failures. They dig some of the potatoes out and cover some up. On harrowing after them many more potatoes appear, and on digging the rows some may still be found. My experience has been that the potatoes left in would more than pay for digging by hand. They may be useful for small growers on a light soil, and for those who, being short of labor, wish to save part of their crop. Six to ten hands and two horses will dig one and a half to two acres per day. In the Southern States early potatoes are plowed out, and ten cents per barrel is paid for picking them up.

3. *Mechanical Diggers.*—The high-priced horse-power diggers, as the "Reuther" (Fig. 43), the "Hoover" (Fig. 44), and the "Dowden," are all reported as satisfactory machines. They work on the same principle. The shovel-point is forced under the

row of potatoes, and the row lifted and deposited on the elevator, which gradually shakes out the soil and leaves the potatoes in a row on the ground in the rear. These require two to four horses, according to conditions, and do better work on soils free from stones.

The Standard Digger is different. A divided shovel

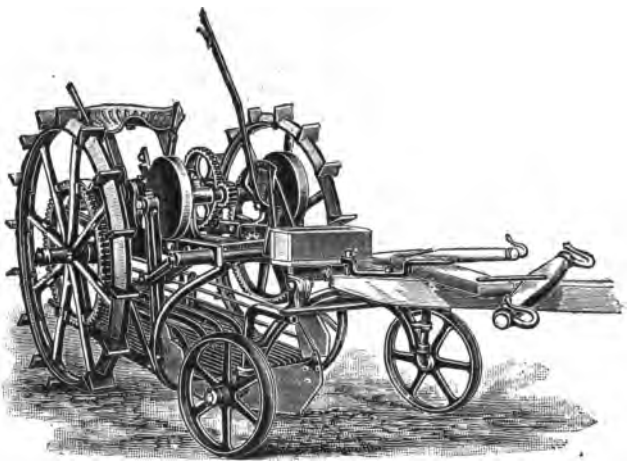

FIG. 43—THE REUTHER POTATO DIGGER

lifts the row onto a shaker, which separates the potatoes and soil, leaving the latter on the surface behind. This digger works well when potatoes are ridged or planted shallow, but when deep it does not do so well.[1] One other form used successfully in Canada and Great Britain consists of a strong frame on two wheels and a small wheel in the front and rear. It carries a set of revolving forks working at right angles to the share,

[1] Minn. Bul. 52, p. 439.

CHAPTER XIII

STORING

POTATOES may be stored in the open in piles covered with straw and earth, in cellars or root-houses, according to the climatic conditions.

Piles.—These are useful for temporary storage in the North. Dig a trench about 3 or 4 inches deep, 3 feet wide, and as long as desired; make the bottom per-

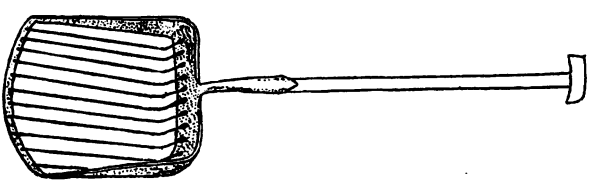

FIG. 45—POTATO SHOVEL

fectly level and firm, so that a potato shovel (Fig. 45) may be used on it when moving the potatoes. Throw the soil from the trench onto each side, making a bank about 15 inches wide with it. This will give a trough about 7 inches deep in which to empty the potatoes. Pile the potatoes neatly, so that the face of the pile at the center will be 3 feet or so high. When sufficient potatoes are stored, place about 3 inches thick of rye or wheat straw (oat straw being liable to heat and become mouldy) with the butts down and heads up on the sides and one end of the pile, leaving the other end for additional potatoes (Fig. 46). Then cover the straw

with soil, beginning at the bottom and piling it toward the apex; 2 or 3 inches thick will be sufficient near the top with the straw, and 6 or 7 inches at the base. Finish the surface off by patting it with the spade so

FIG. 46—STORING POTATOES IN PITS
Useful in climates where the winter is not severe.

that it will turn rain. Dig a channel all around the pile, using this soil for the covering. The bottom of this channel should be below the floor of the pile, and have an outlet to let off water, thus insuring a dry bottom for the pile. Leave the ridge of the pile open to permit the moisture to escape when the potatoes "sweat." If it is desired to hold the potatoes in these

piles over winter, more soil or old hay must be put over them as the frost comes on. The mouth of the pile should be closed at night, and care should be taken to have no potatoes left on the ground at night. Rain or frost may come on and injure them, or retard the work. Sufficient covering must be put on the piles to prevent the rain and sun discoloring the potatoes. I have known a whole crop ruined by inattention to this point. The rain browns them, and the sun makes them green and unsalable. This method is not advisable in the Northern States unless one is sure that they will not want to sell or put up the potatoes until spring, as the pit cannot be opened during frost or in wet weather, and in spring moving potatoes on wet land is objectionable.

Cellars.—If seed potatoes only are held, they may be kept in trays, bushel boxes, or barrels, storing these so that air can circulate under and round them, or they may be held in bins.

Construction.—The location of the cellar should be dry and well drained. It should be built underground, of concrete, brick, or stone walls, with a plastered ceiling if a building is above it, to make a dead air-space between the plaster and the floor. Concrete walls are readily made with clean gravel, sand, and cement, with boards to hold the material while settling. Use one part of Portland cement, three of sand, and six of gravel; mix the sand and cement, then add the gravel; wet and mix, and fill into the wall-space. To hold it in position while drying it is customary to use 1-inch boards, nailed onto 2 x 4-inch studding, which may be placed 1 foot 6 inches on centers. To pre-

vent sagging, the studding of one side is braced to that on the other side by ⅞ x ⅛-inch iron strips, which are placed three feet apart each way, and nailed to the studding on each side. These are left in the wall, and the ends cut off when the boards are taken down. Apertures through which to shoot the potatoes should be left at intervals. One satisfactory cellar of which I know has a driveway through the center and bins on each side. The bins are about 10 feet wide and are filled 4 to 6 feet deep. Divisions are put in as desired.

Ventilation and Temperature are most important. The potatoes must be kept cool, about 33° F. being a favorable temperature. If possible, lead air through a deep underground drain-tile into the cellar; the length of the tile should be sufficient to warm the air a little in winter, and the outside end of it should be covered to prevent the entrance of vermin. A ventilator on the roof will remove warm air. Have a raised board floor in each bin and a ventilator running from it up through the tubers at intervals. Have double doors at the entrance and the shoots, and keep the place dark. Darken the windows if there are any. A small cellar can be made if desired, but make the roof high enough to work in—say, 8 feet. Purchase a reliable thermometer and hang it in the cellar, an oil-stove and radiator, and, if the temperature is going down too low, warm the place. It is folly to have potatoes freeze to save ten cents worth of kerosene.

The advantages of a cellar are:

1. You can see how the crop is keeping.
2. The conditions can be controlled.
3. The potatoes can be sold at any time.

Losses in Storage.—Potatoes suffer loss in weight in keeping in addition to any loss due to disease or insect attacks. At Cornell University, during the past winter, the variety Sir Walter Raleigh, stored in crates in a cool cellar, lost 12 per cent. in weight between the date November 6, 1903, and April 27, 1904, a period of 173 days, while the variety Carman No. 3 lost nearly 10 per cent. Neither variety had sprouted at all. This seems to show that in this district the latter is better for storage, and growers have noted this. Sir Walter Raleigh seems better adapted for selling from the field than for storage. No doubt other varieties vary in the same way, and the same variety will vary under differing conditions. At the Michigan Experiment Station a barrel of potatoes stored September, 1893, had lost 5 per cent. in weight by March 28, and 11.5 per cent. by May 1, 1894. Research shows that these losses are influenced by temperature and the state of moisture of the air. The higher temperature increases the loss, while the higher moisture content diminishes it. Light seems to have little influence upon the loss of weight, but is injurious because it diminishes the selling value of the potato. The average percentage losses of twelve varieties of potatoes carefully stored in a cool cellar at a temperature of 42° to 51° F. during seven months, as recorded by E. Wollny,[1] are: October, 2.02 per cent.; November, 1.18; December, .50; January, .50; February, .81; March, .41; April, .50; the total loss aggregated, on an average, 6.17 per cent. In every case the losses were

[1] E. S. R., III., p. 493.

greatest directly after digging, and in February the losses were higher than the month before or after. The size of the tuber, or whether the variety was early or late, had no perceptible influence. The three early varieties lost from 4.87 to 8.48 per cent., the five medium-early varieties from 4.55 to 6.78 per cent., and the four late varieties 5.71 to 7.28 per cent. These losses are believed to be lower than those usually assumed and observed. The loss of weight of these tubers from May to October was 21.57 per cent., considerably more than their loss from October to May 1. As soon as the sprouts begin to grow the loss is rapid.

Nobbe found that about 75 per cent. of the loss of potatoes in storage is due to loss of water and 25 per cent. to respiration. As the potato is alive and breathes, its existence depends upon its using some of its stored-up energy. A ferment changes some of its starch into sugar, and this sugar is used to furnish energy. At low temperatures sugar formation continues, but respiration and the use of the sugar diminishes, and at 30° F. to 28° F. (2° to 4° below freezing-point) respiration almost ceases; hence, frozen potatoes taste sweet because of the accumulation of sugar.

E. Wollny believes that between 32° and 50° F. is the best range of temperature for holding potatoes.

The actual losses which may occur in storage as the result of disease cannot be definitely stated.

CHAPTER XIV

PRODUCTION, TRANSPORTATION, AND MARKETS

In the North the potato is a quasi-staple product. It can be kept a number of months in storage. In the South, except in cold storage, it cannot be kept long and is purely a garden-truck crop, but its culture is extending.

2,836,196 farmers grew potatoes in 1899. The area was 2,938,952 acres, and the yield 273,328,207 bushels, valued at $98,387,614. The average value of the product per acre was $33.48, that of all crops was $10.04, while that of all vegetables was $42.09 per acre. The price per bushel varied between 22 cents in Iowa and Nebraska to $1.10 in Arizona, the average price being 36 cents. The average yield[1] per acre in the year 1879 was 96.7 bushels; in 1889, 83.6 bushels, and in 1899, 93 bushels per acre, although yields of 300 and 400 bushels are common, and over 800 bushels have been obtained.

In 1900 six States grew 51 per cent. of the potatoes (Figs. 47, 48)—viz., New York, Wisconsin, Michigan, Pennsylvania, Iowa, and Minnesota—while Ohio, Illinois, Maine, Kansas, Nebraska, Missouri, Indiana, and California grew 25 per cent. more. The sandy pine belt region, skirting the lakes, has shown a phenomenal increase in potato production. In Maine,

[1] Consult Twelfth Census Report 1902.

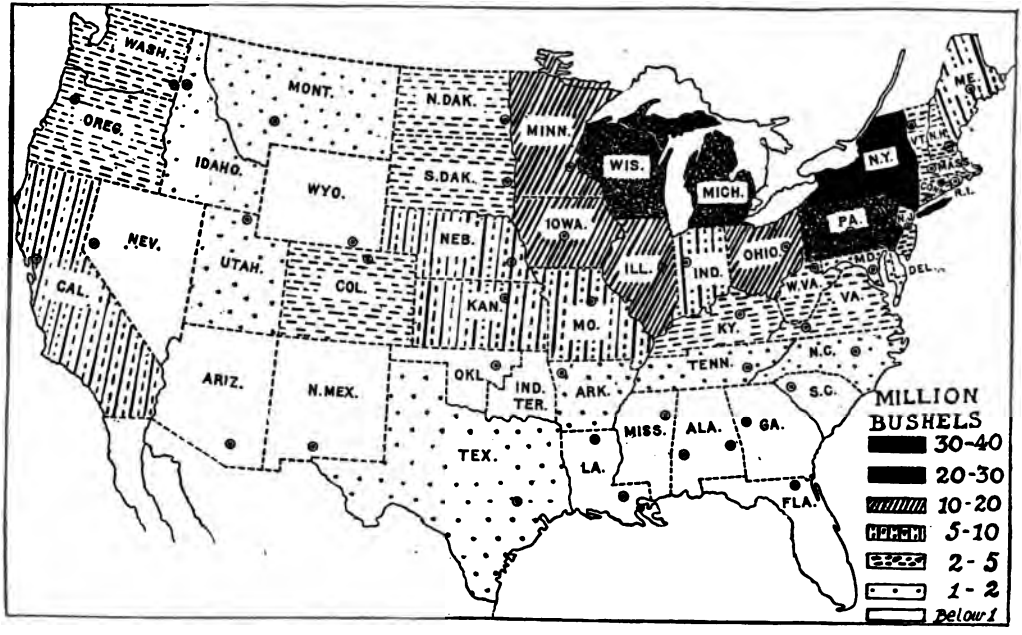

FIG. 47—SHOWING THE DISTRIBUTION OF POTATO PRODUCTION IN THE UNITED STATES IN 1899
(Data from Twelfth Census Report)

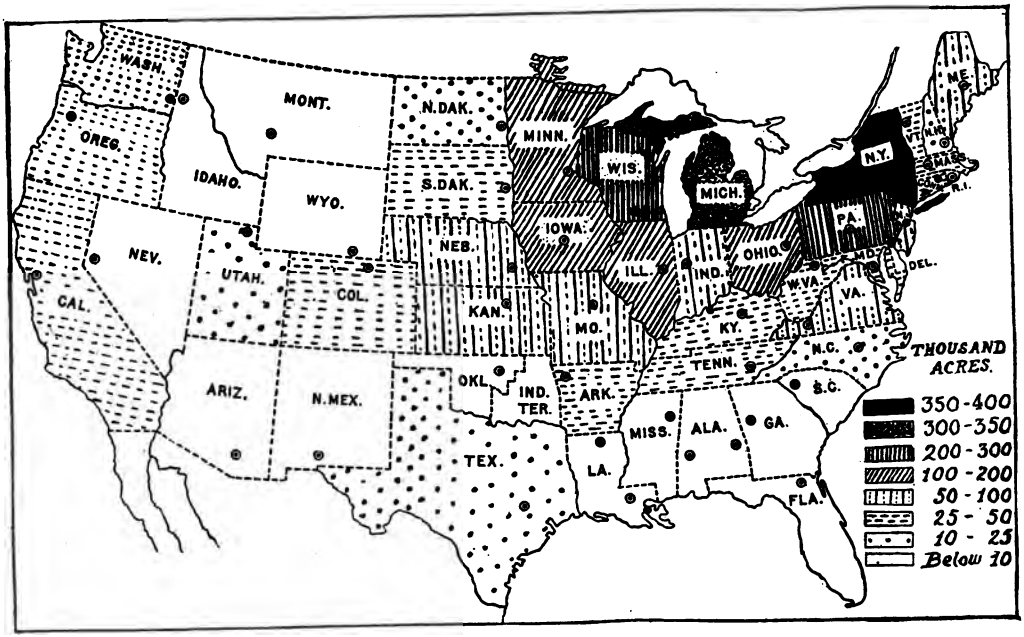

FIG. 48—SHOWING THE DISTRIBUTION OF THE AREA IN POTATOES IN THE UNITED STATES IN 1899
(Data from Twelfth Census Report)

Michigan, Wisconsin, and Minnesota the potato acreage has increased faster than the population in the past ten years. New York comes in the same belt. The per capita production of potatoes in the United States is given as about 3.5 bushels.[1] About one-third of the total crop of the Southern States is shipped North as early potatoes, and some late potatoes are shipped back from the North. The consumption north of Mason and Dixon's line is about 4½ bushels per head, exclusive of potatoes used for seed or starch-making. The South consumes a relatively small amount, being less than 1½ bushels per capita.

Knowing the approximate consumption and the area and condition of the crop (obtained from the United States Department of Agriculture reports, which are posted monthly), the farmer can form an idea of the outlook of the business. Thus, in 1903 there were 2,916,855 acres grown, and the yield as now known was 247,127,880 bushels. The table below will show the uses to which this crop was put. In 1904 as large an area would need to be planted (a larger one ought to be, because the population is increasing); hence, 10 bushels of seed are allowed per acre on:

	Bushels
2,925 000 acres	29,250,000
Plus 10 per cent. loss in storage . . .	2,925,000
Used for starch-making, etc. (largely small potatoes, etc.)	5,000,000
Available for human consumption . . .	209,952,880
	247,127,880

[1] Consult Twelfth Census Report, 1902.

The public can consume about three bushels of potatoes per head per year, and as there were 79,000,000 people to be fed, it would require 237,000,000 bushels to furnish this quantity. The shortage of 27,000,000 bushels insured a fair price, 61.4 cents per bushel being the average farm value.

The States having a surplus of potatoes are the Southern and Eastern Coast States (notably Maine, Rhode Island, New Jersey, Virginia, and Florida), their market being the cities of the East and interior. The Trans-Mississippi and Nortwestern States also have a surplus.

The potato trade is a home trade. The yield is seldom more than is required for home consumption, and several times it has been less—as in 1902, when over 8,000,000 bushels were imported.

Factors Influencing Farm Prices.—Farm prices are the net value of farm products to the producer upon delivery at the local market. Between the grower and the consumer profits must be made by the local buyer, the wholesaler, the retailer, and perhaps a broker or two, and the transportation companies. To yield a profit to the grower the price received from the consumer must exceed (1) the expenses of distribution, including transportation, (2) the cost of production. It may not. The market price is regulated by the law of supply and demand.

In marketing live stock, cotton, grain, tobacco, and wool the main tendency is to eliminate the expensive middle man. This is easier accomplished with nonperishable products than with perishable ones. There are three reasons why the expensive middle man has

been retained in the marketing of perishable products—

1. The extraordinary risks of depreciation.
2. Insufficient capitalization of the distribution end.
3. Absence of large-scale handling of the products.

There is little consolidation in marketing potatoes. Generally speaking, selling on commission is antiquated and should be abandoned, as it is the most demoralizing feature of farming. The market is more stable when goods are bought and sold outright. An interesting feature is that rural districts are doing more of their own banking, so far as the financiering of the grain and some other crops is concerned, and the same will eventually be extended to potatoes. Cold storage improves prices, preventing slumps and excessively high prices, both of which are injurious. High prices inevitably lead to reduced consumption. The absence of public markets where consumer and producer can meet is a noteworthy feature of American cities and towns. Such markets have a salutary effect upon the distributor and middleman wherever they exist. The useless retailers are eliminated and the service of the survivor is improved, and both producer and public are benefited.

One important cause of this lack of system is the poor roads. Hauling is high. It costs, on an average, 25 cents to haul a ton of produce a mile, and in many cases more. 90 per cent. of all the freight handled by the railroads is brought to them on wagons; most of it is farm produce. With team and man at $3.50 per day, the cost of hauling this freight aggregates about as much as the cost of running the railroads

one year. It is useless to double the production of the farm unless we increase the facilities for marketing the produce, and to do this it is imperative that we have good highways. In Belgium loads of farm produce are hauled 60 to 70 miles in competition with the railroad. Let every farmer join the good roads' movement; then he will be able to go to market with produce on days when the land is too wet to work or when the price is high. How many miles will $1.25 haul a ton of potatoes or other farm produce on a road, a trolley road, a railroad, and on water?

$1.25 will haul a ton 5 miles on a common earth road; 12½ to 15 miles on a well-made macadam road; 25 miles on a trolley road; 250 miles on a steam railway; 1,000 miles on a steamship.

The value of cheap steamship transportation is seen in the Eastern potato trade. The prices of potatoes are better sustained in the Central States than in the Eastern because, although the tariff of 25 cents per bushel is an ample safeguard for the producer, as soon as potatoes are 50 cents per bushel, wholesale imports from Europe and the West Indies are apt to prevent them from going much higher.

The South Atlantic States, from Florida to Virginia, supply the early potato trade of the Eastern cities. The water transportation enables them to handle large quantities at low rates, and to compete with Northern potatoes (old) during at least three months of the year.

Modes of Selling.—1. *The Local Market.*—This deserves attention, as higher prices are received in it by the producer than when shipped away.

2. *The Distant Market.*—Many growers must ship. For such, combination is essential. The method adopted by the Eastern Shore potato farmers (Virginia) is noteworthy. There are 2,500 shippers in the Exchange. They sell all their produce through selected receivers, appointed by the directors, in New York, Boston, and Philadelphia. The receivers charge 8 per cent. commission, of which 3 per cent. is given to the agent who solicits the business. This agent should be familiar with the market requirement and give instructions in regard to methods of grading, assorting, and packing, and in this way render the produce more valuable. Combinations such as the following commend themselves: the use of the "registered label," which is similar to a "union label," and is placed on all packages, or a trade-mark similar to that used by the Farmers' Produce Association, of Delaware, which carries the number of the shipper, and enables the selected salesman to inform the grower at once if anything is wrong.

FARMERS' PRODUCE ASSOCIATION OF DELAWARE (27)

The contents of this package are

GUARANTEED

to be as good all through as on top

Commission Rates.—In Cleveland potatoes are sometimes sold on a commission basis of 4 and 5 cents per bushel, or 10 per cent. of the sale price. In St.

Louis the wholesaler purchases and makes his profit by selling to large customers and hucksters at an advance of 10 cents per bushel over what they cost him in car lots.

In Cincinnati the rate of commission is 3 cents per bushel. In Kansas City the brokerage for handling is 2 to 2½ cents per bushel. In Richmond, Virginia, and Atlanta, Georgia, if not sold by the grower, 10 per cent. is the commission. In Lincoln, Nebraska, when potatoes retail at 80 cents per bushel, the money is divided about as follows: Retailer's share, 20 cents; wholesaler's share, 10 cents; railroad freight, 18 cents; seller's commission, 7 cents; net price to producer, 25 cents; 69 per cent. of the cost to the consumer goes to pay the transporters and distributors, and 31 per cent. to the grower. At Portland, Oregon, the commission is 5 per cent., and the burlap sacks in which the potatoes are handled cost about 5 cents each. The retailers sell at an advance of 10 to 30 cents per sack (100 pounds). At New York and Philadelphia 8 and 10 per cent. commission will find good salesmen. The producer usually receives, net, between 25 and 65 per cent. of the retail price of potatoes. Taking a number of market returns, they show that the producer's returns are about 63 per cent. of the price paid in the markets, and of this, in some cases, about half is paid to the railways for transportation if the goods are sent by rail, so that, then, roughly speaking, the producer, transporter, and distributor divide the customer's money equally. The value of a local market, where the producer can sell direct to the consumer, is apparent.

Grading.—The proper grading of potatoes is essential to success. Scabby, second-growth, ill-shapen, diseased, and undersized tubers must be removed from first-class grade. The grading may be done by having a sand screen on trestles set at such an angle that the potatoes roll down into baskets at the bottom, while the dirt falls through, and the seconds and refuse are thrown into baskets or boxes on the side. Let two men sort and one shovel, and have one emptying and bagging if they go into bags. A sack-holder is a convenience in filling the bag. The small potatoes and dirt may be removed by a potato-sorter (Fig. 49), of which there are several types on the market.

Packages.—Potatoes are sold by the pound, peck, bushel, barrel, cental, and car lot. The early potatoes are shipped in barrels holding 3 bushels (180 pounds). A canvas cover is nailed on the head. Such barrels cost about 20 cents, including the cover. The late crop is sometimes shipped in bulk in car lots. In the East seed potatoes are shipped in double-headed barrels containing 165 pounds, net. Such barrels cost, new, about 30 to 33 cents. Flour-barrels are often purchased at about 15 cents each instead. The high price of new barrels leads some to ship seed potatoes in strong burlap sacks which hold the same amount as a barrel. The sacks cost 15 to 20 cents less than the barrel. Boxes are used for shipping small quantities. On the Pacific Coast burlap sacks holding a cental (100 pounds), and costing 5 cents each, are used.

Barrels.—Before filling, drive the hoops firm on the bottom and nail with shingle nails; drive on the bulge

FIG. 49—GRADING AND BARRELING POTATOES FOR MARKET

hoops, and secure with 3 or 4 barrel nails; then proceed to fill. The potatoes should be shaken down occasionally while filling, and the barrels filled full, and, if headed, the head should be put in where it belongs with a screw press, so that the potatoes cannot rattle. The head should be nailed firmly with shingle nails. If in bags, sack them up well, and tie tight; or sew up, according to requirements.

Bushel Boxes.—For marketing early potatoes in the local market bushel boxes or crates are often used. T. B. Terry uses a bushel box 13 x 16 inches and 13 inches deep, all inside measurement. The sides and bottoms are of ⅜-inch, and the ends are ⅝-inch, white wood. Hand-holes are cut in each end, and the upper corners are bound with galvanized hoop iron to strengthen them. They cost $25.00 to $30.00 per hundred at the factory, and weigh 6 to 7 pounds each. Each box has a lid, so that in changeable weather the potatoes can be picked up and covered as fast as dug. This box holds five pecks. The legal bushel for grain is 2,150.4 cubic inches, and in measuring potatoes the rule is to heap the half-bushel measure sufficiently to add one level peck to the two level half-bushels. Five level pecks are held in 2,688 cubic inches. These boxes hold 2,700 cubic inches when level full; hence, they may be piled three or four high on a wagon. The recent introduction of a crate in which the sides fold onto the bottom when not in use reduces the amount of storage room required by about two-thirds. These crates cost the same as others, and appear to be equally strong.

Advantages of a bushel box:

1. Potatoes are put in the boxes and covered as soon as dug, thus preventing them from heating in the sun.
2. They are easily and quickly loaded on a wagon, saving time.
3. They are convenient packages in which to carry early potatoes to the home market.
4. The potatoes may be left at the store in the box and delivered in the box when sold, saving handling and bruising.
5. When drawing the main crop to the storage-cellar they are convenient to handle.
6. They may be used for storing seed potatoes, apples, etc., and carrying seed potatoes to the field to be planted.

CHAPTER XV

CHEMICAL COMPOSITION AND FEEDING VALUE

Composition.—Early attempts were made to determine the food value of the potato by means of chemical analyses. In 1795 Pearson reported "Experiments and observations on the constituent parts of the potato root." Einhof published analyses of the potato in 1805, as did Vanquelin in 1817. Rather more than fifty years ago Emmons in this country reported analyses. Lawes and Gilbert devoted considerable time to the study of the composition of potatoes, and more recently various agricultural experiment stations, notably the Connecticut State and the Minnesota Agricultural Experiment Stations, the Division of Chemistry, U. S. D. A., and various European institutions have been investigating the problem. The approximate chemical composition of a number of varieties is: Water, 75 per cent.; protein, 2.50 per cent.; ether extract, .08 per cent.; starch, 19.87 per cent.; fibre, .33 per cent.; other non-nitrogenous materials, .77 per cent.; ash, 1 per cent. A more extended analysis is taken from the Vermont Experiment Station, report 1901:

TABLE XII

Water	*Dry Matter*	*Starch*	*Dextrine and Soluble Starch*	*Reducing Sugars*	*Crude Fibre*	*Crude Protein*	*Ether Extract*	*Crude Ash*	*Undetermined*
Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
79.41	20.59	14.51	1.35	0.09	0.36	2.28	0.06	1.26	0.68

The percentage of water usually ranges between 70 and 80 per cent., the extremes being 65 and 85 per cent. Potatoes contain more dry matter than any root crop.

	Per cent.
White turnips	7 to 9
Rutabagas	9 to 14
Mangel-wurzels	9 to 16
Sugar-beets	12 to 24
Carrots	10 to 17
Parsnips	10 to 18
Potatoes	20 to 30

About 85 per cent. of the matter is present in the solid portion, or marc, and 15 per cent. in the juice. It has been believed by many that the specific gravity of the tubers varied with the percentage of dry matter, and on this basis tables for ascertaining the dry matter present in the tubers from the specific gravity have been worked out and used considerably. From these data the starch content was determined. Woods,[1] of Maine, and Watson,[2] of Virginia, found that the ratio existing between the specific gravity and the starch content is not fixed.

Starch is the most important constituent of the dry matter of potatoes; it generally constitutes 15 to 20 per cent. of the fresh tubers, but may be as low as 10 or as high as 25 per cent. Maine-grown potatoes are usually lower in their starch content than European-grown potatoes. The starch content varies with the variety and the locality. Northern-grown samples of the same variety usually contain more starch than Southern-grown samples.[3]

[1] Me. Bul. 57, p. 150.
[2] Va. Bul. 55, p. 102; Bul. 56, p. 144.
[3] Va. Bul. 56, p. 144.

TABLE XIII

DIGESTIBILITY OF POTATOES

FOOD	*Animal*	*Dry Matter*	*Nitrogenous Matter*	*Organic Matter*	*Protein*	*Carbohydrates*	*Ash*
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Potatoes, with eggs, milk, and cream	Man	....	....	90.6	71.9	93.0	....
Potatoes, raw [1]	Pigs	97.0	84.5	....	82.0	98.1	44.6
Potatoes, cooked	Pigs	95.0	82.0	....	80.0	97.6	40.0
Potatoes dried [2] and ground	Sheep	80.1	....	81.5	19.5	92.0	....

The above data show that potatoes are almost wholly digestible.

Feeding Value.—When abundant and low in price, potatoes may be fed to all classes of stock. In France, Girard fed 55 to 66 pounds of cooked potatoes per day to fattening steers and 4½ to 6½ pounds to sheep. Von Funke[3] found uncooked potatoes were good for all stock except pigs. He fed 60 pounds of raw potatoes, 6 pounds of linseed meal, and 9 pounds of clover hay, with salt, per 1,000 pounds, live weight, per day to fattening steers. For milch cows, 25 pounds daily per 1,000 pounds, live weight, is the limit. For yearlings, ewes, and wether sheep, 25 pounds per 1,000 pounds, live weight, per day is advised, and fattening sheep, 40 pounds. For horses, about 12 pounds per 1,000 pounds, live weight, may be given with other food. Stock should not be watered soon after feeding potatoes, but preferably about half an hour before feeding. Potatoes[4] are not a valuable food for young animals,

[1] Snyder, Minn. Bul. 42, pp. 89, 90.
[2] Kellner, *et al.* E. S. R., XIV., p. 595.
[3] E. S. R., V., p. 812.
[4] Minn. Bul. 42, p. 95.

as they are deficient in protein and ash—hence, should not be fed to growing cattle under two years old, lambs, or young pigs, unless in very small amounts, with other food to balance the ration. At Wisconsin Experiment Station,[1] hogs ate cooked potatoes better than uncooked, and 445 pounds of cooked potatoes were equal to 100 pounds of corn-meal in feeding value. One pound of dry matter of corn is superior to one pound of dry matter of potatoes for making gains with pigs.

Cooking. — In cooking potatoes a considerable portion of the albumen may be lost. Peeled potatoes started in cold water lost 80 per cent. of albumen, while those started in hot water lost but 10 per cent. Less is lost if the potatoes are not peeled. Salt should be added to potatoes, because the mineral matter they contain is deficient in sodium salts, which are requisite for the human system, and because salt increases the palatability. Varieties vary in the time they require to cook, and even soil and climatic conditions have an influence. In a floury, mealy potato the starch grains have swollen and burst, and ruptured the cell-walls surrounding them, while in a soggy potato this has not taken place. Potatoes showing second growth will not cook uniformly; the last-grown portion will cook first. When second growth takes place the starch passes from the older portion to the new; hence, when cooked, the older portion appears to be hard and dark, while the newer portion is white and floury, the difference being due to the presence or absence of starch.

[1] Wis. Seventh Annual Report, 1890, and Henry, "Feeds and Feeding," p. 212.

Uses.—Potatoes are used as human food, stock food, for the manufacture of starch,[1] syrup, alcohol, dextrin, etc. Potatoes may be preserved as ensilage[2] for stock feeding, while the pomace[3] resulting from starch manufacture and potato feed [4] have received attention for the same purpose. Potatoes may be dessicated, and in this form can be easily preserved in the tropics and arctic regions, and thus furnish an excellent article of diet in a convenient form for transportation. The industry is small at present, but can be readily extended.

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[1] U. S. D. A. Div. of Chemistry, Bul. 58.
[2] U. S. D. A. Farmers' Bul. 79, p. 21.
[3] Me. Sta. Report, 1896, p. 28. Bul. 65, p. 115.
[4] Vt. Bul. 82, p. 72.

CHAPTER XVI

BREEDING AND SELECTION—PROPAGATION AND BREEDING

POTATOES are propagated from seed, cuttings, layers of green shoots, sprouts from the eyes of tubers, or portions of the tubers containing a bud or eye. About the beginning of the eighteenth century Shirreff, of England, wrote that "the potato is to be considered a short-lived plant," and that "the only way to obtain vigorous plants and to insure productive crops is to have frequent recourse to new varieties raised from seed." Dr. Hunter and T. A. Knight held the same views. T. A. Knight stated that late planting tended to reinvigorate a degenerating variety.[1] The value of raising new varieties from seed is recognized to-day, and for their production some modern breeders select as parents two varieties, which in most qualities bear close resemblance to each other, avoiding the use of opposites, the claim being that it is easier to fix the type. Others, including Burbank and Garton, make crosses between widely divergent types, although it takes longer to fix the ones they select and there is a lower percentage worthy of a trial. There is, however, more chance of obtaining something above the average. Wide crosses act upon the characters in the plant in a manner similar to a vigorous push on the pendulum of a clock—it goes higher on each side: plants of higher

[1] Miller's "Gardeners' Dictionary," ed. 1807, "Potatoes," and Don's "Gardeners' Dictionary," 1831-38, Vol. IV., pp. 400-406.

value and plants of lower value than either parent are secured. A plant of high value is secured and grown for a period of years in order to fix it. Those who have regarded the valuable characters which led to the selection of the individual as fixtures from the beginning claim that this period of fixing is solely for the purpose of elimination of the undesirable characters, and that it ought to be termed "the elimination period" rather than "the fixing period." The interrelationship of different qualities is not well known, but it has been noted that a variety having a few thick stalks yields large tubers, but few in number, while a number of weak stalks is often found with a number of small tubers. Early ripening and resistance to blight or rot (*Phytophthora infestans*) are not generally found together. It is claimed that a large production of seed-balls goes hand in hand with a small production of tubers. T. A. Knight claimed that varieties which did not bloom readily could be induced to do so by removal of the soil from round the tuber-bearing stems, the explanation offered being that the plant's failure in tuber production would stimulate the production of seed.[1]

In pollenizing varieties artificially the stamens should be removed from the female parent with fine pincers just as the bloom opens, or before, and the flower enclosed in a paper or gauze bag. The proper time to apply the pollen is known by the moist appearance of the stigma. The pollen from the desired variety should be dusted on the stigma on two or three successive days. The bag may be removed when the stigma dies

[1] Philosophical Transactions, 1806.

and the bloom withers. The fruit, or seed-ball, may contain from 100 to 300 seeds. These are washed from the ripe seed-balls, dried, and at the proper season sown under glass, or in a hot-bed, or out-of-doors in

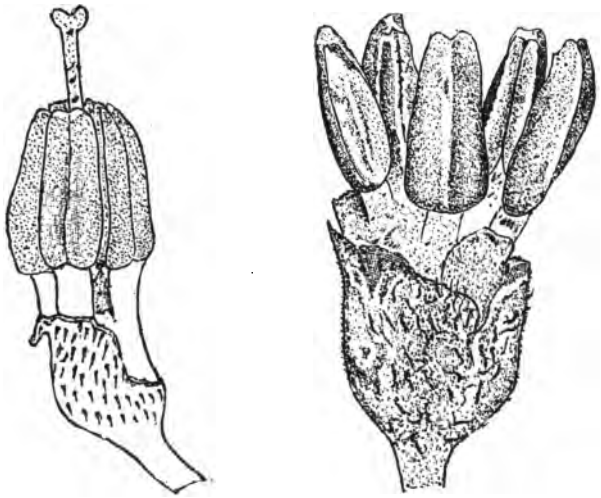

FIG. 50—POTATO FLOWER, WITH CALYX AND COROLLA REMOVED
On the left are shown the anthers closed round the pistil. On the right the anthers are expanded, pistil not shown The inner surfaces of the anthers show the line where rupture occurs when the pollen is liberated. Generally this occurs only near the upper portion of the anther.

flats. The seeds germinate rapidly. Later they are transplanted to a well-prepared piece of land outside. The distance apart varies with different growers—from 12 x 12 to 26 x 26 inches, and sometimes more. The upright stem bears leaves and the axils of the first leaves bear shoots, which turn downward into the ground and bear tubers. The old idea that the first year's

crop consist of small tubers, the next larger, and so on, does not always hold, as a tuber weighing over seven ounces has been produced the first year. The Burbank potato was full size the first year it was grown from seed, and many breeders feel that unless the tubers are of edible size the first year they are not likely to be worth further care. Frequently the tubers do not reach full size until the second year.[1] The tubers from each plant must be kept separate, the best selected and planted again. The distance apart varies between 26 x 12 and 40 x 40 inches. Wider planting permits the study of the individual. The third, fourth, and fifth year field culture is given, and a variety may be found worthy of a name and further trial before distribution. The breeder's aim is to produce varieties which excel in productivity, power to resist diseases, earliness, quality, percentage

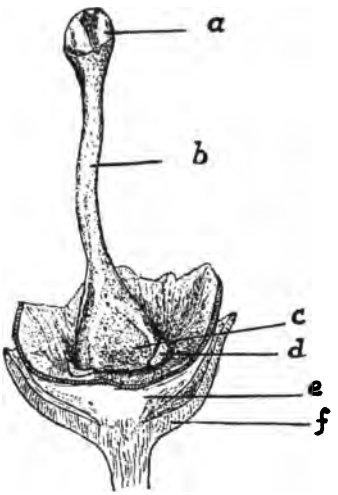

FIG. 51 — PISTIL OF POTATO FLOWER, SHOWING THE PARTS

a—Stigma, where pollen is applied. *b*—Style, down which the pollen tube goes to the ovary, *c*, where it fertilizes the ovule, which become the seeds (see Fig. 3). *d*—Attachment of stamens, removed to prevent self-fertilization. *e*—Petals, partly torn away to expose ovary. *f*—Sectional view of calyx.

[1] Minn. Bul. 87, p. 10.

of starch, and have other desirable characteristics—as, suitable shape, color, depth of eyes, etc.

Selection.—Hybridizing is of small value unless attended by careful selection and vigorous elimination of the poorer types. All potatoes tend to vary in cultivation, either to improve or degenerate. This variation is more marked in some plants than in others; hence, once a variety is established, the yield may be materially increased and the rapid deterioration of the variety prevented by selection of the best plants. Selection must be made in the field, not from the bin. The whole plant must be considered, not a single tuber. Goff[1] showed that by perpetuating the most productive and least productive plants of Snowflake potatoes the total yield of the most productive one for two years was 322 ounces, while that of the least productive was but 100 ounces, and, summarizing fourteen years' trials, the most productive plants yielded 180 per cent. more than the least productive. Bolley, at North Dakota, found that "equal weight pieces from small or large tubers of the same vine are of equal value, provided all are normally mature,"[2] confirmatory evidence that the whole plant is the unit of selection.

Growers may at least maintain the productivity of their stocks of potatoes by careful selection of the best plants when digging, careful storage of these tubers, and then using all of them for seed. These might be planted by themselves on a piece of good land, and se-

[1] (N. Y.) Geneva Report, 1887, p. 85. Wis. Report, 1899, p. 306.
[2] N. D. Bul. 30, p. 243.

lections made from them at the following harvest, the best plants being again retained for the nursery plat and the balance used as seed.

A. Girard,[1] one of the foremost potato growers of France, selects his potatoes every year from those hills whose foliage is especially luxuriant. He uses the variety Richter's Imperator, and prepares the soil to a depth of 12 to 16 inches, giving a liberal application of barn-yard manure and fertilizers, acid phosphate, sulphate of potash, and nitrate of soda. He selects, for planting, tubers weighing from 3½ to 4 ounces. When he cannot get such, he recommends that tubers of 7 ounces in weight be cut in two, and tubers of 10½ ounces into three pieces—always cutting in the direction of the greatest length. He insists on the rejection of all potatoes weighing more than 11 ounces. If the potatoes available for planting weigh less than 3½ ounces he places in each hill several smaller tubers, enough to bring the total weight to about 4 ounces. He lays great stress on the distance between the plants; the rows are 24 inches apart and the tubers are planted 19 inches in the rows, these distances having been determined to be best by careful experiment. He advises early planting, as soon as danger from frost is past. The crop should be well worked and all potatoes kept covered, and the tops well sprayed with Bordeaux mixture, and the crop not dug until all of the tops have withered. Farmers in the co-operative experiments under his direction report yields of 400 to 700 bushels per acre as common, and

[1] E. S. R., V., p. 117.

even up to 1,353 bushels per acre with a starch content of 20 to 25 per cent. One farmer secured almost 10,000 pounds of starch per acre, probably one of the largest yields of carbohydrates ever obtained from an acre of land.

APPENDIX

Spray Calendar

Disease or Insect	*Spray Mixture*	*First Spraying*	*Second Spraying*	*Third Spraying*	*Fourth Spraying*	REMARKS
Early Blight	Bordeaux mixture	When plants are 4 to 6 in. tall	7 to 14 days later	7 to 14 days later	7 to 14 days later	
Late Blight	Bordeaux mixture	As for early blight	do.	do.	do.	Up to 7 sprayings are sometimes given
Rosette	Treat the seed					
Flea-beetle	Bordeaux mixture	When beetles appear	Repeat if necessary	As for 1 and 2		A deterrent only
Colorado Potato-beetle or "Bugs" and Blister-beetles or old-fashioned Potato bug	Paris green or other arsenites in Bordeaux mixture	When beetles appear	Repeat if necessary	As for 1 and 2		1 pound Paris green per acre in 100 gallons or more of Bordeaux mixture. Arsenate of lead, 3 pounds to 50 gallons. Arsenite of lead, 3 pounds to 50 gallons. Green arsenoid 1 pound per 100 gallons.
Grasshopper	Paris green or other arsenites in Bordeaux mixture	When they appear	Repeat if necessary			As for Colorado beetle

Seed Treatment

Disease	*Treatment*
Scab	Soak uncut seed in formalin, 1 pound to 30 gallons of water, for two hours; then dry and plant on scab-free soil.
Rosette (*Rhizoctonia*) .	As for scab.
Dry Rot	Diseased tubers to be destroyed; those in contact with them to be treated as for scab and sprayed as for blight.
Wet Rot (due to Blight or Bacteria)	Have seed potatoes in such storage that they can be examined, and these tubers sorted out and destroyed. Do not plant affected tubers. Soaking them in formalin, as for scab, is advisable in some cases, depending on the cause.
Stem Rot or Dry End Rot (*Fusarium oxysporum*)	It attacks the stem-end first; hence, cutting off this end of suspected tubers will reveal the disease. Discard diseased tubers.

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